FLIGHT and The AIRCRAFT ENGINEER

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The Outlook

Roll Out the Barrel

"THERE is nothing new under the sun." The old saying must occur with startling frequency to anyone who has occasion to refer to historical documents, patent specifications, and publications of that sort. Leonardo da Vinci seems to have thought of most things aeronautical, and since his day schemes and inventions have sprung from the fertile brain of man. The result is that nearly every "modern" idea has, if one looks back far enough, and searches diligently enough, been anticipated. All the main features of present-day aircraft were incorporated in Stringfellow's model. The fundamental idea of rotating-wing aircraft was foreseen in the 'nineties. Jet propulsion began with Heron and his sphere with bent pipes. The coaxial contra-rotating airscrew was, so a correspondent reminds us, exhibited at an Olympia aero show in about 1910. The contra-rotating engine was invented in this country by Mr. Redrup, as a correspondent pointed out in our issue of November 6th. And during the war 1914-18 the German Siemens-Halske firm produced a contra-rotating aircraft engine in which the shaft and airscrew rotated in one direction, the cylinders in the opposite.

And now we have the "barrel" engine under consideration again. Beginning with this issue, we publish an article by an American author and designer who has made a very thorough search of all patents relating to engines in which the cylinders lie parallel with the crankshaft, and the reciprocating motion of the pistons is translated into a rotary motion by various means.

Great Britain can claim to have taken some part in the development of the "swashplate" engine, for an engine of this type was tried experimentally on some Bristol buses several years ago. Before that, the above-mentioned Mr. Redrup produced a swashplate aircraft engine. It was, if we are not mistaken, exhibited on the stand of the Monospar Company (which later became General Aircraft) at one of the last Olympia aero shows. Neither of these two engines came into general use, but it would be unwise to argue from that fact that the barrel engine will never be adopted for aircraft.

Do not let us ever forget, when tempted to condemn something because it has been tried and has failed, the classic example of Mr. Roy Fedden and the Burt-McCallom sleeve-valve engine. The Bristol Hercules, described in this issue, stands to-day as the unchallengeable proof that skill and perseverance can overcome obstacles which may at first appear insurmountable. Many were the setbacks, and many also were the voices which told him that he was wasting his time. Fortunately for the nation, Mr. Fedden has a streak of obstinacy in his make-up, with the result that to-day Great Britain leads the world in the matter of sleeve-valve aircraft engines. A man of less will power might well have given in.

However, we have wandered away from the point in order to impress a lesson. In spite of previous failures it may well be that the barrel engine is by no means "dead." Mr. Hall, the writer of the article, arrives at the conclusion that by taking into account every bit of knowledge we possess, and with certain provisos, it should be possible to build a two-stroke diesel engine of the barrel type capable of developing 5,000 h.p. for a weight of 3,000 lb., with a frontal area of 7 sq. ft. The figures are staggering, and it is not to be expected that they are attainable at once. Much research and

development work will be required first. But even if the results which are practically possible should only represent a portion of those visualised by Mr. Hall, the effort seems worth making.

Significant is the fact that Mr. Hall considers the two-stroke diesel the most promising development in the large sizes visualised. If he is right, and his views are shared by many, it is comforting to think of saying "Good-bye to 100 octane and all that," at least so far as large aircraft are concerned.

Great Events in the Near East

VERY seldom has a Prime Minister of the United Kingdom sent a special message to the forces of all three Services on the eve of a battle. Mr. Churchill's message rings with the spirit of that famous signal which Nelson hoisted as he led his fleet into action at Trafalgar, but it says more: "The battle itself will affect the whole course of the war. Now is the time to strike the hardest blow yet struck for final victory, home and freedom. The Desert Army may add a page to history which will rank with Blenheim and with Waterloo."

That stirring message has been sent to the Mediterranean Fleet, to the Eighth Army, and to the contingent of the Air Force under the command of Air Vice-Marshal Arthur Coningham, for all three are united in the fight. The collaboration of all three is whole-hearted, and if the result is what we all hope, the honour will be shared by all three Services.

The Air Force has had the honour of striking the opening blows by its terrific hammering of the airfields and ports of arrival in Africa no less than the ports of departure in Italy and Sicily, while all the time it has been helping the Navy and its Air Arm to deplete the enemy convoys on their way to Africa. The intensity of these blows has been steadily increased as zero hour approached, until it reached a pitch of fury. The Australian and South African Air Forces are at one with the R.A.F. in this mighty effort.

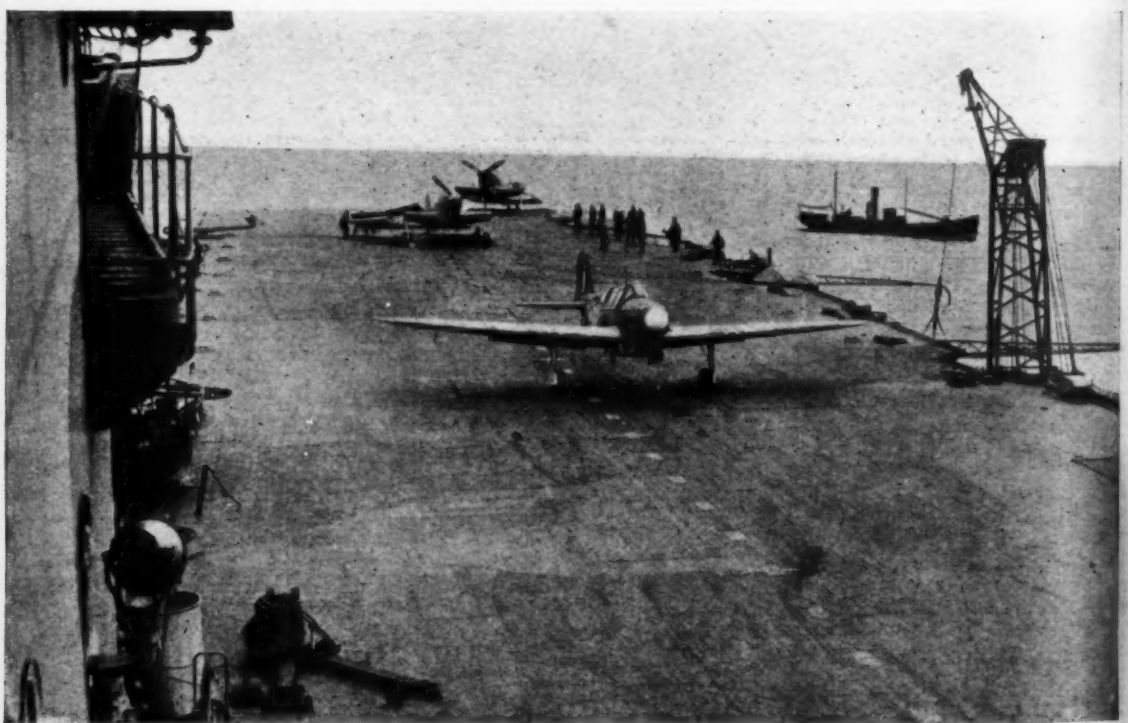
We may assume that it was our air effort which blinded the enemy and so enabled the first advance to take him unawares. The initial rain storms near the coast helped to keep German and Italian aircraft aground, while further inland, where the British Empire Army started its main advance, our own squadrons were able to work with the troops and perform the multifarious air duties which a modern army now requires.

Many times have the airmen of the Empire faced superior numbers of the enemy with success. In this battle we believe that there is no such disparity, and that augurs well for the final result. As the Prime Minister said, all our hearts are with our fighting men.

Condors, Beware

IN the Battle of the Atlantic, or, rather, in the Battle of the Oceans, air power and sea power are inextricably interwoven. Accordingly, *Flight* feels no need to apologise for expressing its delight at the vote of the U.S.A. Congress which permits all American ships to be armed and to enter "zones of war."

This historic decision, coming after the Lease and Lend Act and the determination of the United States to escort her supply ships across the Atlantic, is as important to the Allied cause as a great naval victory would be. It magnifies the power of the British Navy and so enables it to take on further responsibilities. Indeed, it is a great happening, worthy of that instinct for righteousness (which rises above all internal political friction) of the great-souled American people.



OFF TO SHORE BASE: Fairey Fulmars taking off from the flight deck of H.M.S. *Victorious*. The transverse landing wires are not in position so it is probable that the Fulmars will land at their shore stations.

War in the Air

One of our big Atlantic convoys as seen from a U.S. Navy flying boat.

New Campaign in Libya : Great Work by R.A.F. : Enemy Aircraft Waterlogged : Conflict of Tanks and Aircraft

ONCE again the Middle East has struck, and once again it has taken the enemy by surprise. The home public was also surprised. It seems that the R.A.F. played a great part in the first day's dash, on November 18th, of General Sir Alan Cunningham's men for 50 miles into the desert south of Sidi Omar, while the bad weather, consisting of violent sandstorms followed by deluges of rain, apparently blinded the air forces of Germany and Italy and prevented them from giving their Generals timely warning of the British movements. Inevitably the song of Deborah and Barak comes to mind: "The stars in their courses fought against Sisera." One particular instance illustrates the help which the elements gave to the cause of righteousness. A large section of an enemy armoured division got bogged in the mud or wet sand, but it was spotted, and squadrons of South Africans in their Maryland bombers came over and hammered the helpless vehicles with excellent effect. On that day the enemy lost 18 aircraft against only one of ours.

For months past it has been obvious that the Axis has been making great efforts to reinforce its troops in Libya. We know that from the numbers of daring attacks which our own aircraft and submarines have been making on the convoys bound for Tripoli and Benghazi. Very many ships have been sunk, but numbers must have got through. One has noticed of late increased references to larger numbers of tanks being used by the enemy in the skirmishing round Tobruk and Sollum, and this was significant. Almost nightly the R.A.F. and the S.A.A.F. bombers have been pounding the harbours of the enemy on the African coast, and in the last few days there have been raids almost every night on the harbours of Naples and Brindisi, which are the main points from which the convoys start. It was obvious that something was working up, and the question in the minds of observers in Great Britain was whether it would be a strong enemy attack on Egypt or a British attack on Libya. Now we know that, whatever the enemy

FROM DEMOCRACY'S ARSENAL: Tomahawks are being assembled and test flown in Burma before being handed over to the Chinese Air Force. If the Burma Road were cut it would have no effect on this traffic.

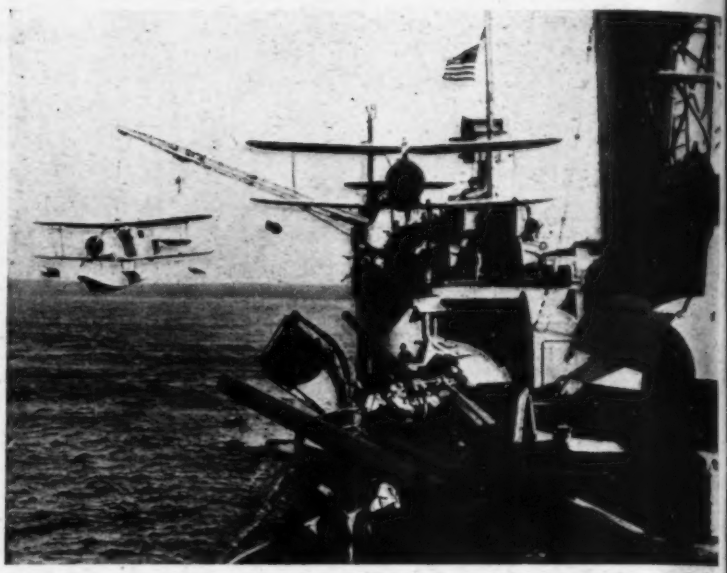
WAR IN THE AIR

may have wished to do, General Cunningham has taken the initiative. From the success of his first dash it is clear that he has been able to rely on a highly satisfactory degree of air superiority.

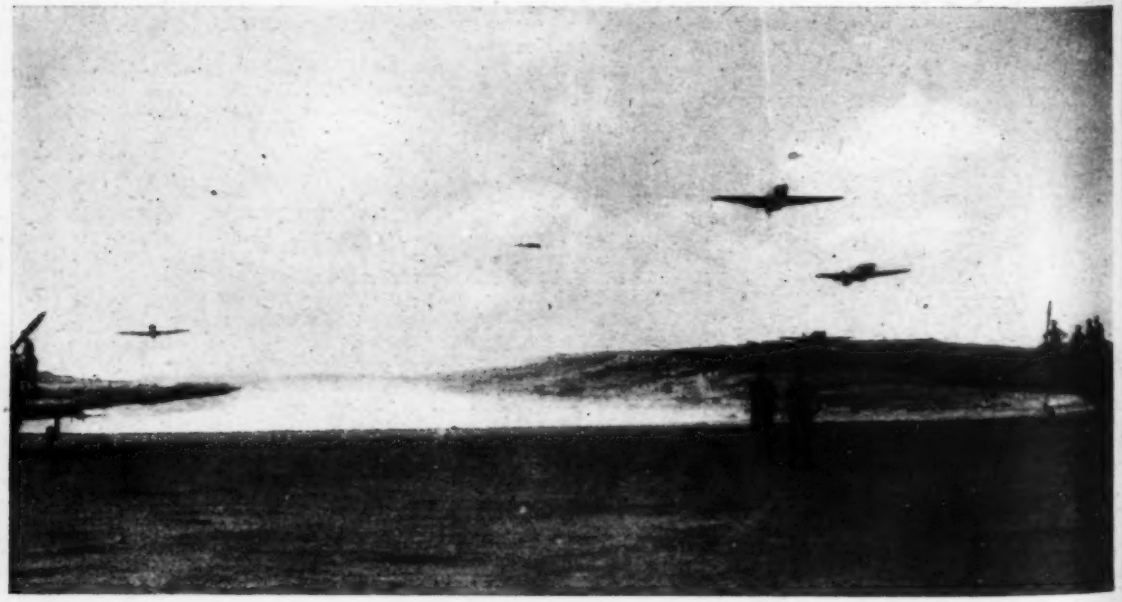
Of course, the enemy must have realised the possibility of this move by the British, though, even so, we were able to achieve a surprise in our initial movement. It is possible that it was expectation of a British advance which made Germany press Vichy to recall General Weygand from his post in French Africa. He is loyal to Marshal Petain personally, but no willing collaborator with the Germans, and it would not be agreeable to the latter to have to meet a British advance on the east with a very doubtful quantity in their rear on the west.

Above all, this advance is part of a British strategic plan. There have lately been demands by well-meaning but thoughtless people for a British landing in western Europe as a diversion to help the Russians. In very sarcastic words Mr. Churchill told the House of Commons that the War Cabinet had not overlooked this possibility. Now we have established a new fighting front, and one which should create the maximum of embarrassment for the enemy. We have not had to force a landing in the teeth of carefully prepared defences, for our troops and their air component are already established in Egypt and East Africa. Of course, it is admitted that it is difficult and dangerous for us to get reinforcements through the Mediterranean, but we have another way round. It is long, but it is now in regular working order, and, moreover, troops, air squadrons and supplies of all sorts can come up from South Africa, and across from India, Australia and New Zealand with a minimum of risk and difficulty. It is noteworthy that H.M.S. *Prince of Wales* has been at Capetown.

If all continues to go as well as the first move has gone, this attack will bring cheer to the Russians as they struggle on gamely to hold the Germans and their satellites away from the oilfields in southern Russia and from the roads leading to the Caucasus. It is too soon to say for certain that a British success in Libya would force the enemy to withdraw troops from the Ukraine front, but there are great strategic possibilities about this British advance. The Germans and Italians could not afford to lose all Cyrenaica and Tripolitania without making a great effort to hold them. Recent reorganisation of the British (the word including all Empire forces) in the Middle East has made separate provision for campaigns in Libya and in the Persian-Caucasus front at the same time. Complete victory in the former would set free



KEEPING OPEN THE SEA LANE : Swinging out single-float Vought-Sikorsky OS2U-1 seaplanes from a U.S. cruiser on the Iceland patrol.



TO PROTECT MALTA : Hurricanes taking off from an airfield in Malta to intercept Italian bombers which have been signalled.

ENEMY AIR LOSSES TO NOV. 22nd.

	Over G.B.	Over Continent	Middle East
Nov. 16	2	0	5
,, 17	0	0	0
,, 18	0	1	18
,, 19	0	0	10
,, 20	0	0	37
,, 21	0	0	10
,, 22	0	6	4
	2	7	84

Totals: North, 5,557; over 2,248. Middle East —

most of General Cunningham's army for service on the other front.

It will be remembered that that very sound strategist, Field-Marshal Smuts, recently foretold that the Armageddon of this war would be fought round the Mediterranean or the Middle East, and the recent conferences of General Wavell with General

The death of Gen. Udet has been announced. His career is outlined on this page.

Auchinleck and with the Imperial General Staff in London suggest the same thing. More unlikely things have happened than that the British should, at the appropriate moment, perhaps next spring, cross the Caucasus in strength to bring aid by land and air to the Russians.

The effect on other nations should also be considered. The Italians must always be wondering whether the British will invade their country, and

BRITISH AIR LOSSES TO NOV. 22nd.

	Over G.B. A'crft.	Over Continent B'brs.	Ftrs.	Pilots	Middle East A'crft.
Nov. 16	0	0	0	0	1
,, 17	0	0	2	2	3
,, 18	0	0	0	0	1
,, 19	0	0	0	0	3
,, 20	0	0	0	0	9
,, 21	0	0	0	0	5
,, 22	0	0	1	1	13
	0	0	3	3	35

Totals: North, 3,024; about 512. Middle East, —

perhaps the recent account in *Flight* of the training of British parachute troops has not conduced to their peace of mind. They still have a fairly powerful navy, consisting of five battleships, 14 cruisers, 82 destroyers and torpedo boats, and about 80 submarines, but nothing would give Admirals Cunningham and Somerville greater satisfaction than a real trial of strength between the British and Italian fleets. The Italians must by now have a great respect for the torpedoes of the Swordfish (even though the *Ark Royal* is no more) as well as for the overwhelming fire of our warships. Then, the Arab world is very susceptible to success or failure of either side in their part of the world, and Arab goodwill is not unimportant. The Turks, cool-headed observers of military affairs, have lately been subjected to a good deal of pressure from the Axis, and will feel in much better case to resist it if the British near by are in a winning mood. If they were to be attacked they would need a good deal of help from British tanks and aircraft.

GOING DOWN: A Heinkel He 111 with its starboard engine on fire after being attacked by a Coastal Command Hudson.

The Battle

THE enemy was taken by surprise by the speed of the initial British thrust, and soon the great battle joined in earnest. It has been a melèe which at first could not be clearly reported to G.H.Q. in Cairo either by the commanders engaged or by the war correspondents with them. One fact emerges clearly from all the reports received up to the moment of going to press, namely that the ground troops and the air forces of the Empire are fighting in unison, and that for the first time since we declared war on Germany British troops are receiving really adequate air help in a first-class battle. The aircraft used by the Empire are mainly, it seems, of American design and construction, as are many of the British tanks, for it has been a deliberate policy for some time past to entrust the equipping of the Middle East very largely to the United States, which has simplified transport problems. It also emerges that, while the British forces of all descriptions have taken and kept the initiative, our air squadrons have likewise kept the upper hand in the air.

Air Vice-Marshal Coningham told a war correspondent that the Tomahawks were keeping the Stukas out of the air. "They dare not send them up," he said, "as long as there are Tomahawks about." The rain storms near the coast have waterlogged many of the enemy's airfields, and that too has been a help, while reports indicate that our air raids on those airfields have done much destruction. Since the episode of Stavanger, the bombing of airfields has been regarded as giving rather poor returns for the energy expended, but the results in this Libyian battle appear to have been good. The enemy has been rushing air reinforcements across from bases in Sicily and elsewhere, and the number of Me 109F machines encountered has gradually increased. But they may not be able to turn the tide of battle. Our own machines have been attacking the columns of reinforcements and supplies which the enemy has been trying to move up, and many lines of communication have been blocked by wrecked lorries and other vehicles.

Gen. Udet has been killed, and a few days later the Germans lost Col. Mölders (who is said to have destroyed 117 hostile aircraft) in a crash near Breslau. Udet was a fighter pilot in the last war; he has been an aircraft constructor, has flown for the films (The White Hell of Pitz Palu), and ended up as Quartermaster-General of the *Luftwaffe*.

FIGHTER-BOMBER Squadron

Hurricane bomber silhouetted against cumulus cloud.

"Flight" Visits a Squadron of the R.C.A.F. which Flies Hurricane Bombers : Ground Defences go Up to Shoot Down

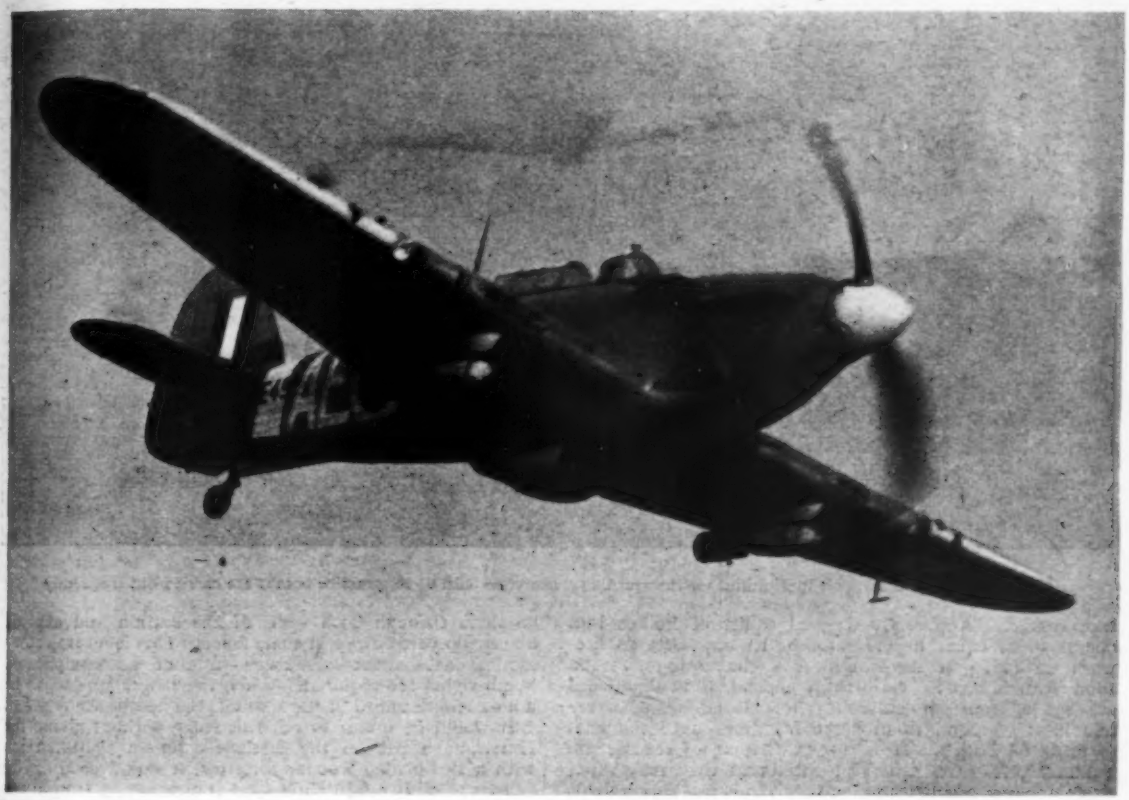
MR. CHURCHILL, when reviewing the war situation recently, recalled that in the last war, when every possible shortage had been predicted, all that we actually ran short of was Huns. To-day some of our Hurricane bomber squadrons are already in that predicament. The occupied coast aerodromes from which the *Luftwaffe* issued to be slaughtered in the Battle of Britain last year are now but advanced landing grounds held by a minimum of personnel. The coast roads on which last spring the German army tramped daily to and from their invasion practices are now deserted of military traffic. If a ground-strafing Hurricane pilot is lucky enough to find a lorry full of German soldiers on which to train his battery of guns he immediately becomes the envy of his squadron. Doubtless, a certain amount of the absence of garrison is due to the necessity to make good some of the losses on the Russian front, but the daylight sweeps of Fighter Command have had a big effect.

Of all the many excitements which may fall to the lot of an R.A.F. pilot in wartime—and there are plenty—there is just nothing to touch this ground strafing for sheer thrill. Merlin roaring flat out, A.S.I. showing over 300 m.p.h., over a hedge, round a tree, under or over a high-tension cable as opportunity affords, aim between two factory chimneys, a last jink to put the ground gunners off. Now the Brownings blaze with a noise like ripping calico as the thumb presses the gun trigger on the joy stick. Steadying for a fraction of a second while the bombs are released and then away into any convenient cloud for cover or more hedge hopping until out of range once more. A few minutes' madness and it's all over. Formation is picked up on the leader and course set for home at an economical cruising speed.

Recently we visited one of the new Hurricane bomber stations and were able to chat with the pilots about some of their experiences on the other side. Unfortunately, as

The 250 lb. bombs fit snugly to the streamline racks. They are suspended from that portion of the wing which is already strengthened to take the guns.

HURRICANE BOMBER SQUADRON



A Hurricane flies low past the camera. All the guns and bombs are carried clear of the slipstream.

is the case with all war reporting, the most interesting parts of the proceedings are secret, and it would be more than foolish to help the Hun in the slightest degree.

The pilots who were our hosts belonged to a squadron of the Royal Canadian Air Force who arrived in this country at about the lowest ebb of our fortunes. They have been on operations for some while now. In the operation from the evening of November 7th until the evening of the following day—which constituted the greatest day of the R.A.F. to date—they supplied a number of the 300 aircraft which Fighter Command sent over the Continent during those twenty-four hours. The Hurricane bombers, with three squadrons of Spitfires as an escort to look after the upper air, swept in with only the difference between the height of their own flying field and that of the French cliffs showing on their altimeters. For a target they had been allocated a factory which was known to be on war work for the Germans. With hundreds of thousands of bullets squirting from the eight Hurricanes' guns to keep the ground defences' heads down their sixteen 250-lb. bombs were placed well and truly in the target area. As they turned for home the short-time delayed-action bombs exploded and the whole factory was seen to burst into flames.

A target which is always popular with the pilots is the odd electricity

Canadian armourers re-arming a Hurricane while the pilot stands by in readiness.

HURRICANE BOMBER SQUADRON

In addition to the numerous opportunities for the real thing, exercises with 8½ lb. practice bombs are carried out frequently.

transformer. Apparently a good squirt of bullets into one is quite equal to the set-piece at any Brock's fire-work display. It seems almost a shame to spoil the show with a bomb As already indicated, these attacks are made from an extremely low level, using every fold in the ground to hide the machines until the final moment of attack. It is a fact that the Germans are building 30ft. A.A. towers in order that they may shoot *down* on to our Hurricanes as they zip across flying fields and other targets at over 500 ft./sec. We cannot imagine these towers are very popular with the crews who man them. This very low flying foxes every form of detection, and if it were not for the approach having to be made from the sea, complete surprise would be achieved more frequently than it is. What usually happens is that the shore guns open up while our pilots are still some three miles out to sea. The Germans have, on occasion, tried this ground-strafing with their Me 109 fighter-bombers, but they seem to prefer cloud cover for the approach.

Bombing from this height brings in its train problems of its own. To be reasonably safe from the explosion of an ordinary 250 lb. bomb, the aircraft must be at a greater height than 1,500ft. Over 2,000ft. is a good deal more comfortable. It is for this reason that short-fused, delayed-action bombs are used to prevent the pilots from blowing themselves up. For the same reason the attack is made roughly in line abreast. If line astern were used, the last man would stand an excellent chance of being blown up by the bombs dropped by the leader. Bomb ballistics also present a considerable problem. The bomb when it hits the ground from such a low height ricochets along in the horizontal position. More in the nature of a shell fired at point-blank range than the accepted idea of a nearly vertical trajectory. This effect is all to the good when fairly massive targets, such as power stations or marshalling yards, are attacked, but one pilot who watched another aircraft attack a railway station saw the bombs go clean through both walls of the station and explode about 300 yards away in some fields. This level trajectory carries one distinct advantage in that no complicated bomb sights are required. When the target appears to be a nose length ahead of the spinner, the bombs are released.

It would be unfair to tell this story without giving the Hurricane a pat on the fuselage. As an eight-gun job with a two-bladed wooden airscrew, it was a good fighter in 1935. With a v.p. three-bladed airscrew in 1939 it was better. A more powerful Merlin to-day maintains a higher maximum speed for the Hurricane than the original type, despite the fitting of 50 per cent. more machine guns or four 20 mm. cannon, or a combination of machine guns and two 250 lb. bombs.

Pilots who fly the bomber version are quite confident that they could fit two 500-pounders without sacrificing much in the way of performance.

With the guns and bombs all carried outside the airscrew disc it would be expected that manœuvrability would suffer somewhat. This, however, is not the case, and the pilots are quite definite on this point. Of course, if an unlucky bullet stops the engine, the stalling speed does go up a good deal with the added resistance of a dead air-screw.

ADVERTISED GOODS

THE fact that goods made of raw materials in short supply owing to war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

The Allotted Span

SOME confusion has been caused by the discrepancy between the general arrangement drawing of the Avro Manchester in our issue of November 13th, 1941, and the printed measurement of 90ft. 1in. for the wing span.

The original official figure gave the Manchester a span of 80ft. A second official communication quoted this figure as 90ft. 1in. We are informed that this second measurement is the correct one. The length is 70ft. and the height 19ft. 6in.

Canadian Lancasters

THE Lancaster bomber which, as announced by Mr. Howe, Canadian Minister of Munitions, is to be built in Canada at the request of the British Government, is one of the latest of our growing fleet of four-engined bombers.

No details of its design have yet been disclosed in this country, but reports from a Canadian source state that it will be powered by four Bristol Hercules engines and that not only will it carry a very great bomb load, but it will be one of the fastest four-engined aircraft ever designed.

Fourteenth of the Second Series

FRIEND or FOE ?

An American and Italian Fighter : Mohawk and Macchi C.200

CURTISS MOHAWK. Back-swept leading-edge and curved cut-away elevators to tailplane. Low aspect-ratio fin and rudder follow similar lines. Tailwheel retracts into bulge.

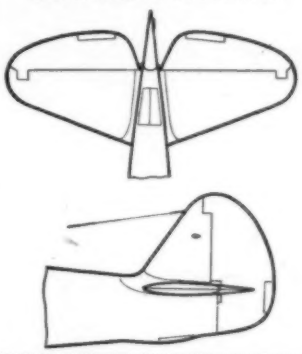
THE Curtiss Mohawk pairs off very aptly with the Macchi C.200 in this series not only because they are both radial-engined low-wing single-seater fighters, but because both are encountered in the Middle East theatre of war.

The American fighter was on order in fairly large quantities for the French Government before that country's collapse, and these were taken over by Great Britain, arriving here with their instruments marked in French. A number of Mohawks are in use with the R.A.F., but more of them are being flown with success by General de Gaulle's pilots in Africa and the Mediterranean area, the Curtiss Tomahawk with Allison liquid-cooled engine being the chief Curtiss product equipping our own fighter squadrons in that part of the world.

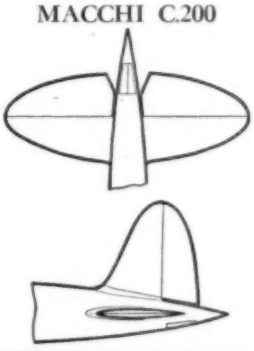
The Macchi C.200 is probably Italy's fastest single-seater fighter and, with the Fiat G.50, constitutes standard equipment for the *Regia Aeronautica*. It is said to be "in quantity production," but neither in quantity nor quality has it very seriously troubled the raiding Marylands—or, to be more precise, its Italian pilots have not.

The Mohawk, like nearly all American machines, has a particularly well-proportioned and graceful tail unit. The tailplane itself, as will be seen from the accompanying drawings, has a generous backsweep to its leading-edge with nicely rounded tips that blend into the curve of the elevator trailing-edges. These are cut away to permit rudder movement, and the corners of the "bite" are also rounded off just clear of the inset trimming tabs. Fin and rudder conform to the same general style, having a slope of approximately the equivalent angle on the leading-edge, and a rounded apex the curve of which continues down the trailing-edge in a graceful sweep that joins up smoothly with the bottom line of the fuselage. The fin and tailplane are faired into the top line of the fuselage by a neat fillet, and the roots of their respective leading edges are in line.

CURTISS MOHAWK



MACCHI C.200

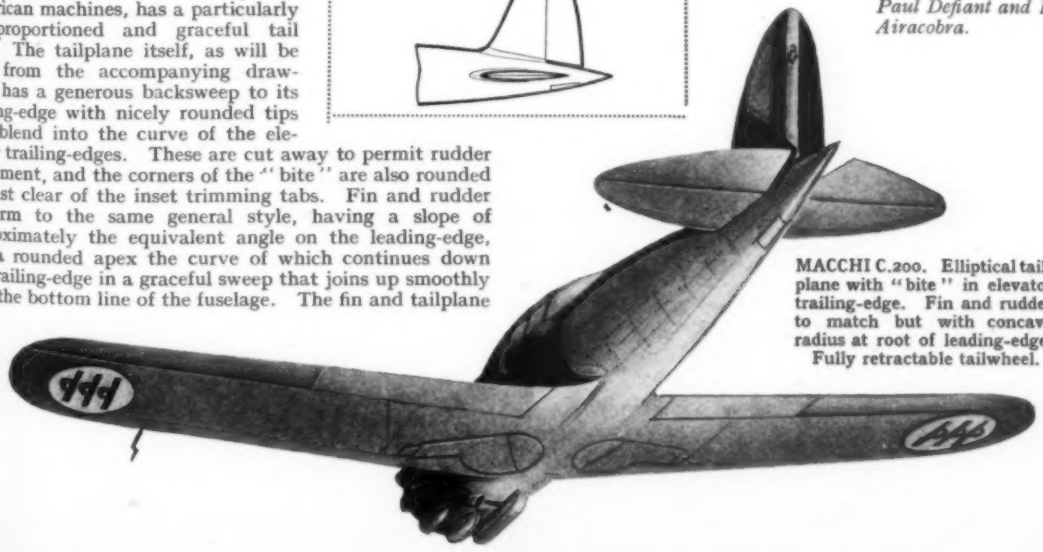


The tail of the Macchi is no less pleasing to the eye—one feels sure it is particularly pleasing down the gun-sights of a Curtiss!—but in this case the ellipse is the favoured geometrical form. The tailplane, in fact, would be a perfect ellipse were it not for the "bite" in the centre of the trailing-edge where the elevators are cut away.

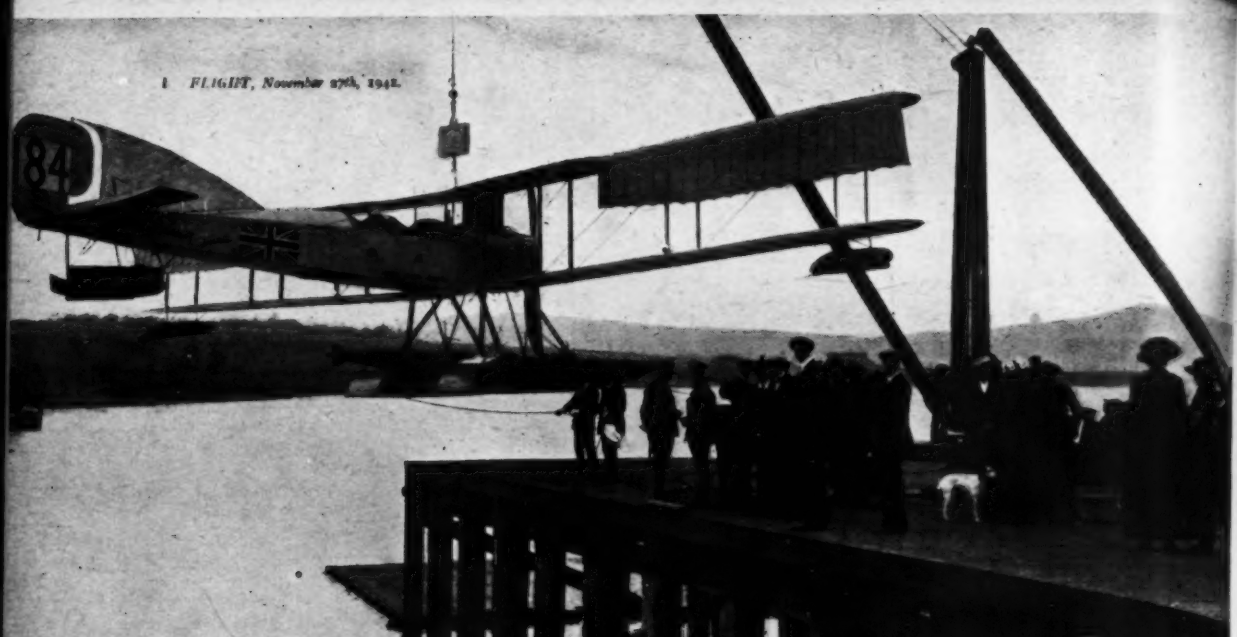
The Macchi's vertical surfaces follow the same general form as the tailplane except that the apex is somewhat broader and the fillet at the foot of the fin's leading-edge gives a small concave radius.

The tail wheels of both machines are fully retractable, but the housing of that of the Mohawk imparts a slight bulge to the underside of the fuselage. Another feature of the American machine visible from any underneath angle is the undercarriage fairing beneath each wing. On this machine the legs fold backwards while the wheels turn through 90 degrees, but the undercarriage of the Macchi folds inwards.

Next week : Boulton Paul Defiant and Bell Airacobra.



MACCHI C.200. Elliptical tail-plane with "bite" in elevator trailing-edge. Fin and rudder to match but with concave radius at root of leading-edge. Fully retractable tailwheel.



TORPEDOES and AIRCRAFT

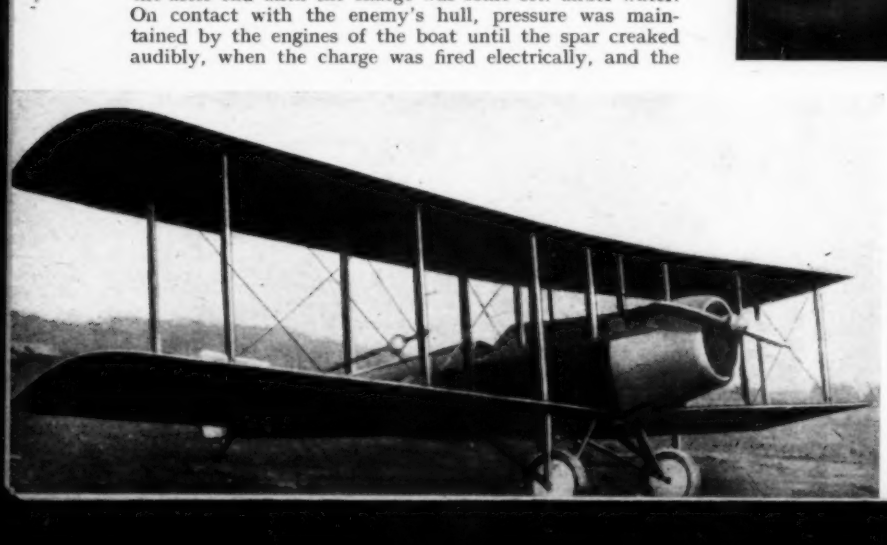
The Short 225, which was the first aircraft successfully to attack a ship with a torpedo.

Over Hundred-year-old Method of Sinking Ships : Torpedo Aircraft of Two Wars

THE name "torpedo" was given by Robert Fulton in 1805 to his idea of exploding a charge of gunpowder under water in contact with the hull of a ship. As an idea it was splendid, but, like belling the cat, there was the one trouble of getting the torpedo to the enemy ship. This caused no end of bother. Many attempts were made to bring the torpedo in touch with the vessel by letting it drift down with the current or tide, rather in the manner of the old fire ships, but, as might well be expected, this was not a huge success.

The first really useful application was the outrigger torpedo in which the explosive charge was carried on the end of a long spar which projected from the bow of a boat.

All picket boats or steam pinnaces of the Royal Navy up to about 1900 were fitted for these outriggers. A spar some 30ft. long projected through a gallows in the bows and carried on its outer end two 16½-lb. tins of wet guncotton primed with one 2½-lb. tin of dry guncotton. The boat approached the enemy ship, the spar being run out through the gallows and held there by a tackle at the after end until the charge was some 8ft. under water. On contact with the enemy's hull, pressure was maintained by the engines of the boat until the spar creaked audibly, when the charge was fired electrically, and the



(Above) Mechanics erecting torpedoes. A tail unit which contains the engine and gyroscope is in the background. The torpedoes are shown here without the heads which contain the explosive charges. The compressed-air containers are visible.

(Left) The Sopwith Cuckoo of 1916 design. The Admiralty asked for a force of 200 of these in the 1914-18 war.

(1) Fitting an 18in. torpedo in its semi-submerged housing under a Bristol Beaufort.

(2) Inspecting the whiskers, pistol and detonator which fit into the nose of the torpedo. Even a glancing blow on one of the whiskers is sufficient to explode the main charge.

(3) Loading up a Beaufort of Coastal Command. This torpedo may have made its run anywhere from the Norwegian fjords to Bordeaux.

(4) Until recently the Germans have favoured the use of seaplanes for torpedo-carrying. A Heinkel 115 is seen being rearmed.

boat, if still able, made for its parent ship.

Some good work was done by these outrigger torpedoes but their use was extremely hazardous. If the attacking boat was lucky enough to reach its target it was, more often than not, also blown up by the resulting explosion.

Some of the earlier locomotive torpedoes were electrically steered from the discharge point by means of fine wires which were unwound from drums as the torpedo ran. Another type drew its propulsive power from stored-up energy in a heavy flywheel which was spun by an auxiliary engine just prior to the torpedo being discharged.

It was a Scotsman, by the name of Robert Whitehead, who, in 1862, was first to perfect a self-propelling floating torpedo. Built in great secrecy for Capt. Luppis, of the Austrian Navy, this weapon, in like manner to those used to-day, was driven under water by a compressed-air engine. It had a speed of about 5 knots, weighed 300 lb., and carried a charge of 18 lb. of dynamite in the nose. The present-day torpedo with its speed of 40 knots, range of 10-12,000 yds. and its 500 lb. of explosive is, in principle, identical

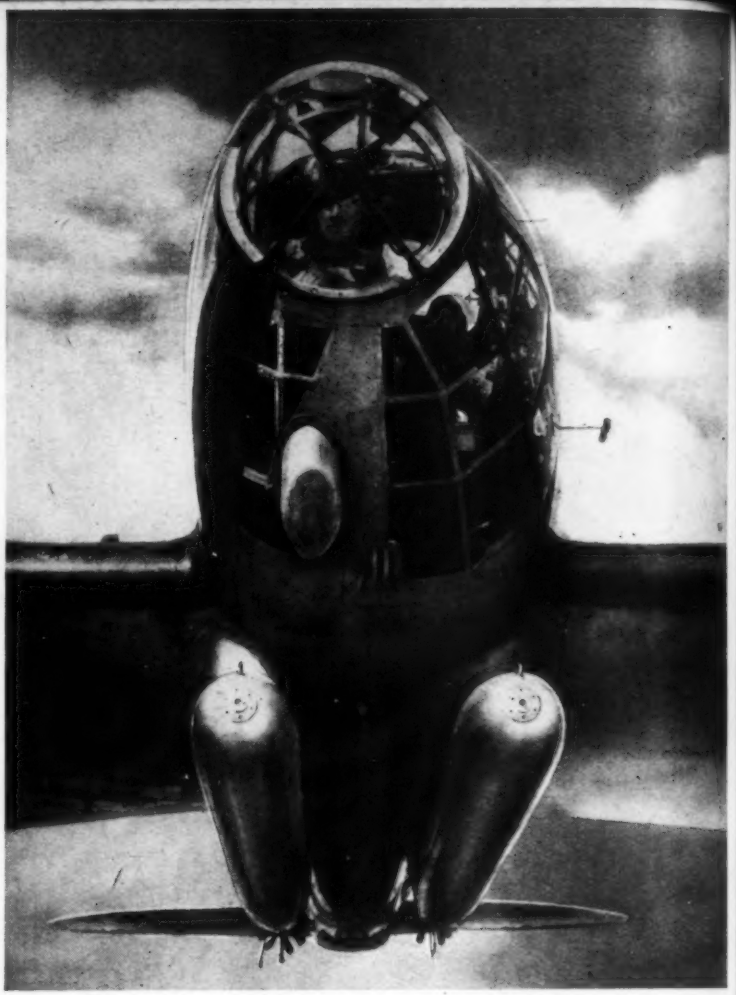
TORPEDOS AND AIRCRAFT

with the original Whitehead except in that it has been found necessary to fit a gyroscope to get accuracy of direction.

When the various navies of the world started to use aircraft, the ship-borne torpedo was already one of the major naval weapons. It is not surprising, then, to learn that much thought and effort was spent in trying to produce a torpedoplane. The first experiments were made about 1911 by Capt. Guidoni, an Italian, who used a Farman biplane and dropped a torpedo weighing 350 lb The moving spirit in this country at the time was Lt. Hyde-Thomson, R.N. A remark which he made in one of his early papers on the subject is worth quoting if only to show, in the light of the present day, how right he was:—

"In any future war there can be no possible doubt that torpedo aircraft will prove to be a weapon of enormous power. They will be a menace to the largest battleship afloat."

As early as 1913 our naval authorities had in mind the attack by torpedoes launched from aircraft against ships which were sheltered and protected from naval attack. The brilliant Taranto action of this war by Fairey Swordfish was thus foreseen 28 years ago.



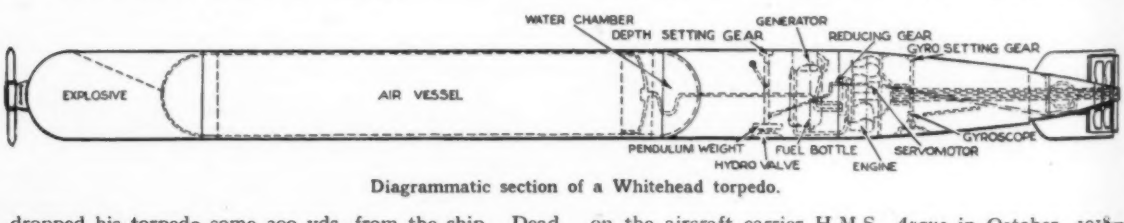
The latest development by the enemy is the carrying of two 18in. torpedoes slung underneath a Heinkel He 111. The two shown here have only practice heads without whiskers or pistol.

Short Brothers, Ltd., who for so many years have catered for things nautically aerial, produced for the naval review of July, 1914, a 160 h.p. seaplane fitted to take a 14in. torpedo weighing 810 pounds. It was, in fact, a Short seaplane with a 225 h.p. Sunbeam engine which made history by being the first aircraft to torpedo a ship. On the 12th of August, 1915, during the Gallipoli campaign, Flight Commander C. H. K. Edmonds, on a Short 225 seaplane from H.M.S. *Ben-my-Chree*, took off from the Gulf of Xeros to attack shipping in the Sea of Marmora. A 14in. torpedo was carried. Near Injeh Burnu he saw a 5,000-ton supply ship and promptly attacked. Gliding down almost to sea level (this was necessary at that time; in fact some of the early attacks were made while the aircraft was actually taxying on the water) he dropped his torpedo some 300 yds. from the ship. Dead on the mark, it exploded amidships and Edmonds had the satisfaction of seeing the ship settling by the stern as he flew away.

It spoils the story somewhat to point out that it was later found that the ship had already been torpedoed by H.M. Submarine E.14, and was beached as a result of the under-water attack. Nevertheless, the ship was finished off as a result of the air attack, and to make sure of having a ship to his own credit Flt. Cdr. Edmonds went out five days later and hit the centre ship of three vessels from a range of 800 yds. This ship was burnt out.

Despite the occasional successes, this form of attack did not progress as quickly as might have been expected. The chief troubles were inherent in the seaplanes of those days. They required all their engine power to get their flat-bottomed floats unstuck from the water, and their structure was so frail that they could be used only when ideal conditions prevailed. Furthermore, even a 14in. torpedo represented a heavy overload, and fuel for only 45 minutes could be carried.

In 1916, however, a torpedoplane with a land undercarriage was produced by Sopwiths (the forerunners of Hawkers) and called the Cuckoo—presumably because it was intended to lay eggs in other people's nests. Considerable numbers of these were built by the Blackburn Company and the first squadron of torpedoplanes embarked on the aircraft carrier H.M.S. *Argus* in October, 1918—rather too late to be of much use, as the war ended a month later.



Diagrammatic section of a Whitehead torpedo.

In comparison with the present-day horse-powers and speeds of our Swordfish, Albacores and Beauforts, the figures of the Sopwith Cuckoo are almost unbelievable. It was an equal span biplane of 46ft. 9in., with a length of 28ft. 6in. The engine was a geared eight-cylinder Vee Hispano Suiza of 200 h.p. Empty, the Cuckoo weighed 1,840 lb. with a gross weight of 3,370 lb. Extreme range, in still air, was 420 miles and maximum speed 100 m.p.h. (This last figure probably meant going downhill slightly.) Wing-loading worked out at 6.4 lb./sq. ft. and power loading at 17 lb./h.p.

WASHINGTON NATIONAL AIRPORT

America's Newest and Finest Flying Field, Designed Throughout by Howard Lovewell Cheney, the American Architect, has Recently been Opened

THE new Washington National Airport, which was opened recently for complete flight operations and is the first project of its kind to be owned and operated by the United States Government, is claimed to be one of the most beautiful in the world.

The terminal building and seven large hangars are designed in a contemporary style of architecture. Their streamlined forms symbolise and express functionally this modern mode of air transportation the buildings must serve. Architectural concrete was used as an exterior building material, with exposed aggregate concrete slabs for interior wall-facing in the public spaces. Terra-cotta is used in the passenger concourses and main public baggage room. Doors, trim, lighting fixtures and ornamental metal are executed in aluminium, with floors and stairs in terrazzo. The ticket and baggage counters are of stainless steel.

One of the innovations in the use of materials is the employment of carved panels of non-breakable plate glass for the balcony rail, which extends the full length of the waiting room, also for the railings of the monumental stairs leading up to the dining room level.

A dramatic feature of the waiting room is the observation window facing the field. The entire east wall is an expanse of glass 25ft. high and 200ft. long; only slightly less in length than the Union Station waiting room! The terminal building and portions of the hangars are on pile foundations. Spread footings are used elsewhere.

The site adjoins the Mount Vernon Memorial Parkway and is only 3½ miles from the centre of Washington. It thus takes advantage of the most desirable traffic route to the various Government offices and the business district. The area devoted to buildings, approaches, parking, etc., was formerly the river bank, of uneven topography. The hilly character of this part of the site was used to advantage in arranging the approaches to the terminal building and in the disposition of field observation parking. The circular entrance plaza at the west front of the terminal building and the approach roads are about 15 feet above the landing field level, allowing ample room for underpasses and terracing.

Hangars and terminal buildings are grouped at the base of a gentle slope rising about the airport and within a V-shaped sector, with the terminal building at the apex of the sector. This was a logical site for the buildings, as the arrangement offers the least possible obstruction to flight operations. The buildings are of modern, fireproof

View of the flying field from the control tower; in the foreground is the instrument board and radio equipment.

WASHINGTON

AIRPORT IN EMBRYO : The 550-acre site of the flying field beside the Potomac River, photographed from the air during construction. Lines indicate the intended position of runways.

construction, adequately air-conditioned and ventilated. The spacious hangars have an overhead sprinkler system and are equipped with very complete and up-to-date shop facilities.

Across the north end of the hangars, extending the full overall length, is an office section which provides for various maintenance and operating departments of the airlines. The largest hangar has a door width of 283ft., with an available clear height of 45ft. This is ample width to accommodate easily the largest of the Army's latest aircraft, the B-19, which has a wing spread of 212ft.

Initially, there are 12 passenger plane stations along the loading ramp. Passenger concourses are so arranged, however, that they can be extended in the future to the south for 500ft. and to the north for a quarter of a mile or more, which will provide for all reasonable anticipated growth. At each station service pits are installed to house outlets for telephones, pneumatic tube stations, air-conditioning and gasoline, thereby eliminating the ordinary use of mobile service trucks on the field. Turntables at each station make possible easy manœuvring of even the largest aircraft.

This is one of the first air terminals in the world which has solved the problem not only of facilitating and adequately providing for the needs of those who travel by air, but also of accommodating, with the least amount of interference with traffic, the thousands who daily visit the airport only for sightseeing. There is complete separation between the circulation of passengers and spectators from the rapidly moving service trucks which carry air mail, air express, and baggage to and from the airport, as well as the deliveries to aircraft.

Considerable attention has been given to the easy movement of passengers in the most direct line of travel to the machines. Ticket counters are conveniently accessible near to the entrances and passenger concourses. Each counter has its own baggage-weighing scales in conjunction with movable platforms which tip the baggage down the chutes to waiting trucks for transfer to the planes.

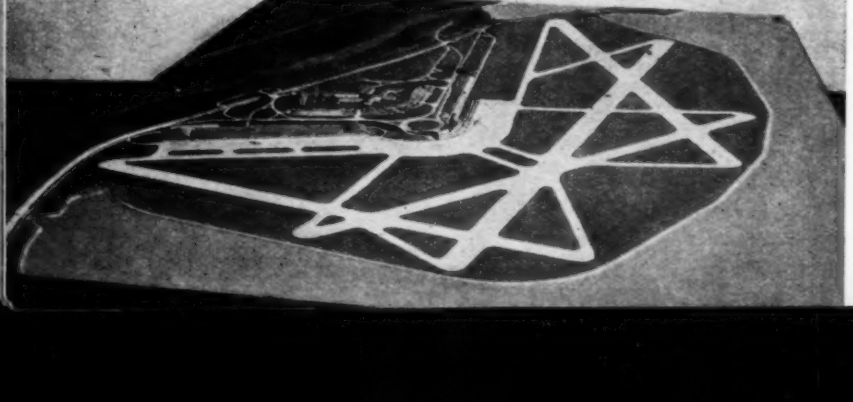
Every effort has been made to provide accommodation for passengers in the terminal building. Barber shop and beauty-parlour facilities are available, valet service, dressing- and rest-rooms, telephone and telegraph, a bookshop and news stand, etc. There is a lunch counter and coffee shop for quick food service, as well as a large observation dining room at mezzanine floor level, which will be distinguished for fine food, an "aviation" atmosphere and a skyward view. During the spring and summer months, one will find the outdoor dining terrace overlooking the flying field a fascinating place.

Expansive Views

Flight observation is the keynote of this new air terminal. Not only will the operator in the centrally placed control-tower atop the terminal building have clear visibility in all directions of the horizon, of every plane landing station, and the entire length of each runway and the hangar apron, but the visitor will be thrilled by his expanse of view from the many vantage points.

Here, too, will unfold an inspiring view of Washington, stretching from the National Cathedral on the west to the Capitol eastward. And in the immediate foreground beyond the landing field are the Potomac River, the nearby parks, the U.S. Army's Bolling Field, and the U.S. Naval Air Station.

Washington National Airport is one of the first projects of its kind in which specialists in "land use design" have worked collaboratively with architects and engineers in the adaptation of the site to its intended function, and Mr. Howard Lovewell Cheney, the planning and supervising architect of it,



Photograph of the approved model of the airport's projected layout. Note the runway pattern.

ONAL AIRPORT

achieved a tremendous success with his great work.

The site has consequently been studied from a somewhat different point of view than that of a purely engineering development. The alignment of the roadways, the profiles of the roadways, the design of parking areas, the moulding and grading of the land, the location of future buildings, the elimination of grade crossings, and the general unification of all these factors have been, as a result, skilfully co-ordinated to take fullest advantage of the site in adapting it to the purposes of the project.

It is hoped that not only will the advanced aeronautical and engineering techniques developed for this project fully justify the claims of its being the most modern airport in the world to date, but that the æsthetic demands imposed upon it will be recognised as having been achieved.

NEARING COMPLETION: Pilot's view of the airport when making a north-easterly approach. The terminal building and No. 1 hangar are finished and five more hangars are under construction.

Constructional Problems

The total airport site area consists of 729 acres, divided into an approximate 556 acres for the landing field and 175 acres for buildings. The landing field proper includes approximately 325 acres of what were tidal flats along the Virginia side of the Potomac River. These were reclaimed with dredged material. The surface was raised from 12ft. to 16ft. above mean low water, shoreward of an encircling levee which was constructed hydraulically. The hydraulic dredges, some of the largest in the United States, pumped 19,500,000 cu. yd of material and completed this phase of the work in the remarkably short period of one year. As the landing field proper was found to be located over a mud blanket 6ft. to 20ft. thick, on top of sand and gravel, adequate measures were required to produce a stable runway fill.

From the shape of the area made available for the landing field, it was logical to develop the pattern of the runways along the lines of what is referred to as the theoretic "Duval Plan" modified to fit the surrounding topography. The four runways have excellent open aerial approaches and are of such length as to permit taking off and landing in all directions. Three sides of the landing field border on the river and can never be obstructed. The fourth is bounded by the highway right-of-way which runs parallel to the Richmond, Fredericksburg and Potomac Railroad right-of-way.

The North-South runway is the longest, and extends in the direction of the prevailing wind. The North-west-South-east and North-east-South-west runways are in the direction of the winds of next frequency. The North-South runway is equipped for blind landing from the south end, which has a clear safe approach over the Potomac for four miles.

This runway and the North-west-South-east runway have a 200ft. width of paving in the centre of the landing strip and a 150ft. strip of firm sand and gravel covered with turf on either side of the paving. The East-West and the North-east-South-west runways have 150ft. of the 500ft. landing width paved.

The length of the runways are: North-South, 6,855ft.; North-west-South-east, 5,210ft.; North-east-South-west, 4,892ft.; East-West, 4,100ft.

At the ends of each runway are two 3,000-watt floodlights focused approximately two-thirds of the length of the runway. Neon units are also installed at the runway ends. A flashing red cross signifies that the runway is not available for landings. When the runway is clear, the cross changes to a green arrow. Runways are outlined by stripes of paint impregnated with fine glass beads to reflect light. Three white stripes outline each runway edge, and two yellow stripes extend along the centre line. Smoke pots are installed on the field to indicate the direction of the wind. The field lighting consists of controlled lights at 200ft. intervals along all runways and taxi strips.

This new airport is directly in charge of America's Civil Aeronautics Authority and finally came into being through President Roosevelt's own vision of the vital importance

An interior view of the waiting room, showing the large observation window facing the airfield.

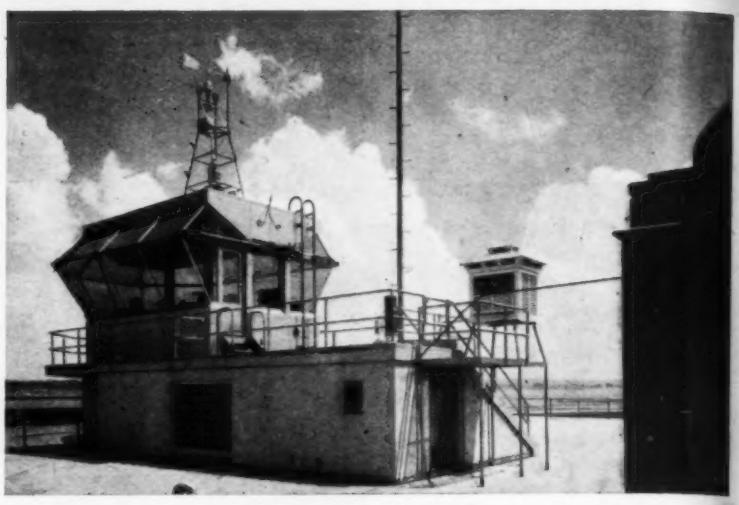
WASHINGTON NATIONAL AIRPORT

of an adequate airport which would serve America's capital in meeting both present and future needs.

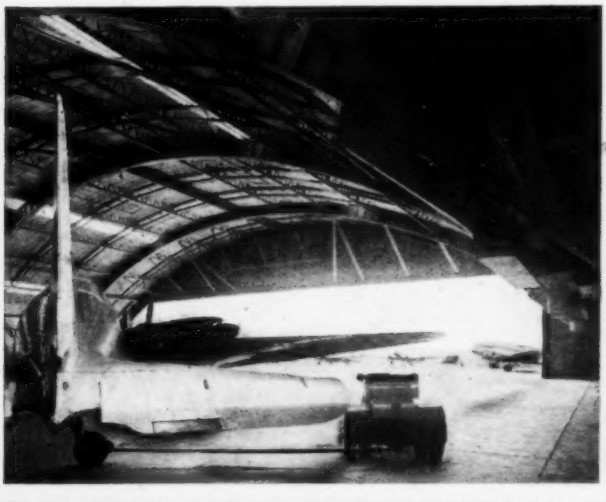
But his decision was the culmination of an extensive study of the question of the most advantageous location for such an airport. Originally sponsored by certain Washington newspapers, the Aero Club of Washington, and the Aviation Committee of the Board of Trade, the first active investigations of a suitable site were begun by U.S. engineers. The National Capital Park and Planning Commission also initiated a long series of comprehensive studies of a number of different sites in and around the Washington district in this search for the ideal position.

These investigations and studies resulted in both the Army Corps of Engineers and the National Capital Park and Planning Commission recommending the Gravelly Point site as the logical area for a centrally located commercial airport, easily accessible to the business and Government centres, and affording ample opportunity for future expansion. It was also mandatory to establish a site with a suitable adjoining area to be developed for the accommodation of seaplanes. The site is also important because it is strategically located in relation to the U.S. Army's Bolling Field and the U.S. Navy's Air Station.

Finally, the Civil Aeronautics Authority, after its own investigation of a number of proposed sites in and around the environs of Washington, recommended Gravelly Point to the President. The site was approved by him on September 27, 1938, and on the following day the Civil Aeronautics Authority announced the plans for its immediate construction.



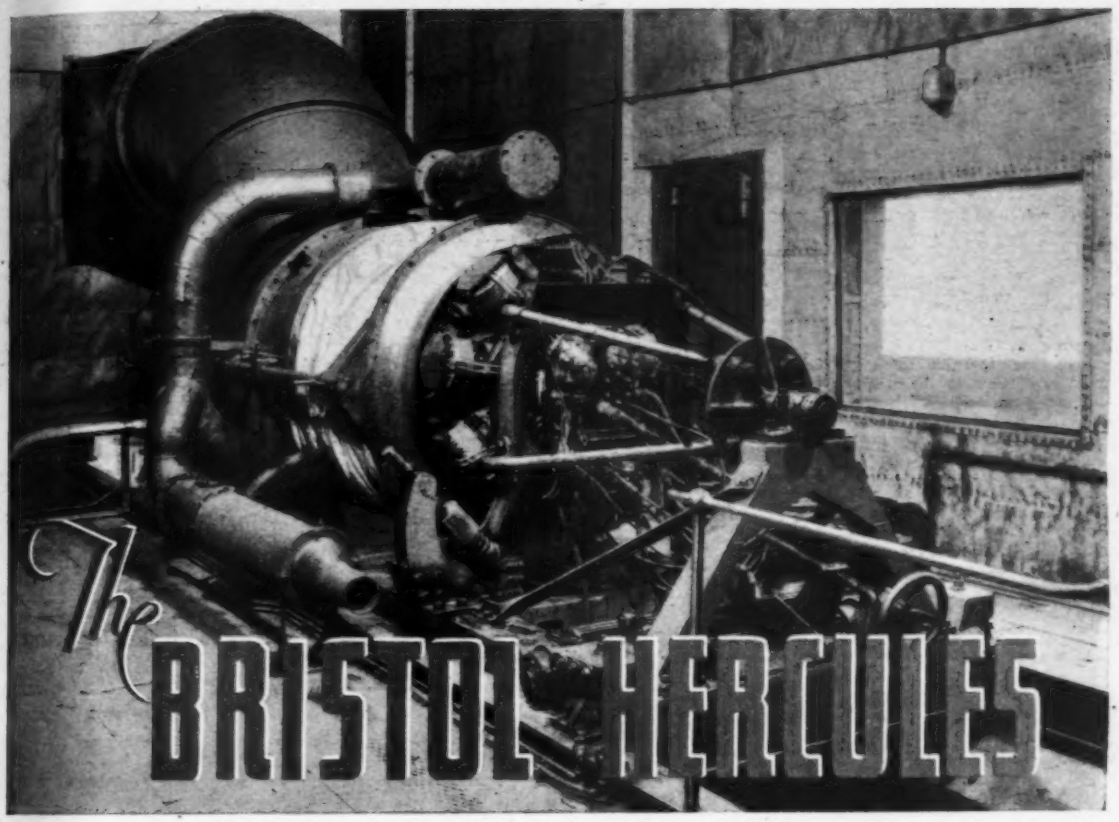
NERVE CENTRE: The control tower above the instrument shelter on top of the terminal building. The corner of the weather bureau is seen on the right.



(Above) The communications room, showing modern teletype installation.

(Left) Inside No. 1 hangar.

(Below) The terminal building as seen from the airport entrance approach.



The BRISTOL HERCULES

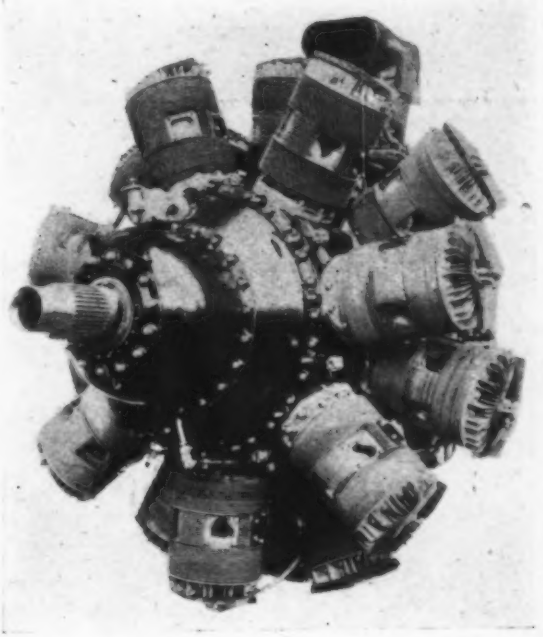
Thousands of hours of bench-testing have gone into the development of the sleeve-valve Hercules. The work began with the testing of single-cylinder units in 1927

14-cylinder Double-row Air-cooled Radial Developing 1,400 b.h.p. for 1,850 lb. Weight: Constructional Features Described

By G. GEOFFREY SMITH, M.B.E.

IF we accept that the heart of a good aircraft is the engine, then the machines which are equipped with the Bristol Hercules sleeve-valve engines are sound. No matter how efficient the design of an aircraft may be, its success must depend entirely upon good general qualities, including the performance and reliability of its engine or engines. Service calls upon bombers, particularly the long-range type, demand a standard of excellence and dependability that can only follow skilful design as well as first-rate materials and finish.

At present in large-scale production at a number of the magnificently equipped factories scattered over this country, the Hercules as a name is familiar to the world at large by reason of its outstanding achievements in leading types of aircraft. The constructional details of the engine, however, are not so well known. In general the Hercules is a double-seven, or fourteen-cylinder air-cooled double-row engine. It has single sleeve valves and a two-speed supercharger. Sleeve-valve engines have been produced in two types. A familiar one is the Knight double-sleeve-valve engine as fitted to Daimler cars of the past, and the other the more simple, single sleeve-valve engine originally made under Burt-McCallom patents and fitted to Argyll cars before the Great War, and actually applied to the first aircraft engine of the type by the Argyll Company of Scotland for the aero-engine competition organised by



For its power the Hercules is a very compact engine. Cooling problems have been assisted by the remarkably close finning and turbulent air circulation over the crown of the head.

THE BRISTOL HERCULES

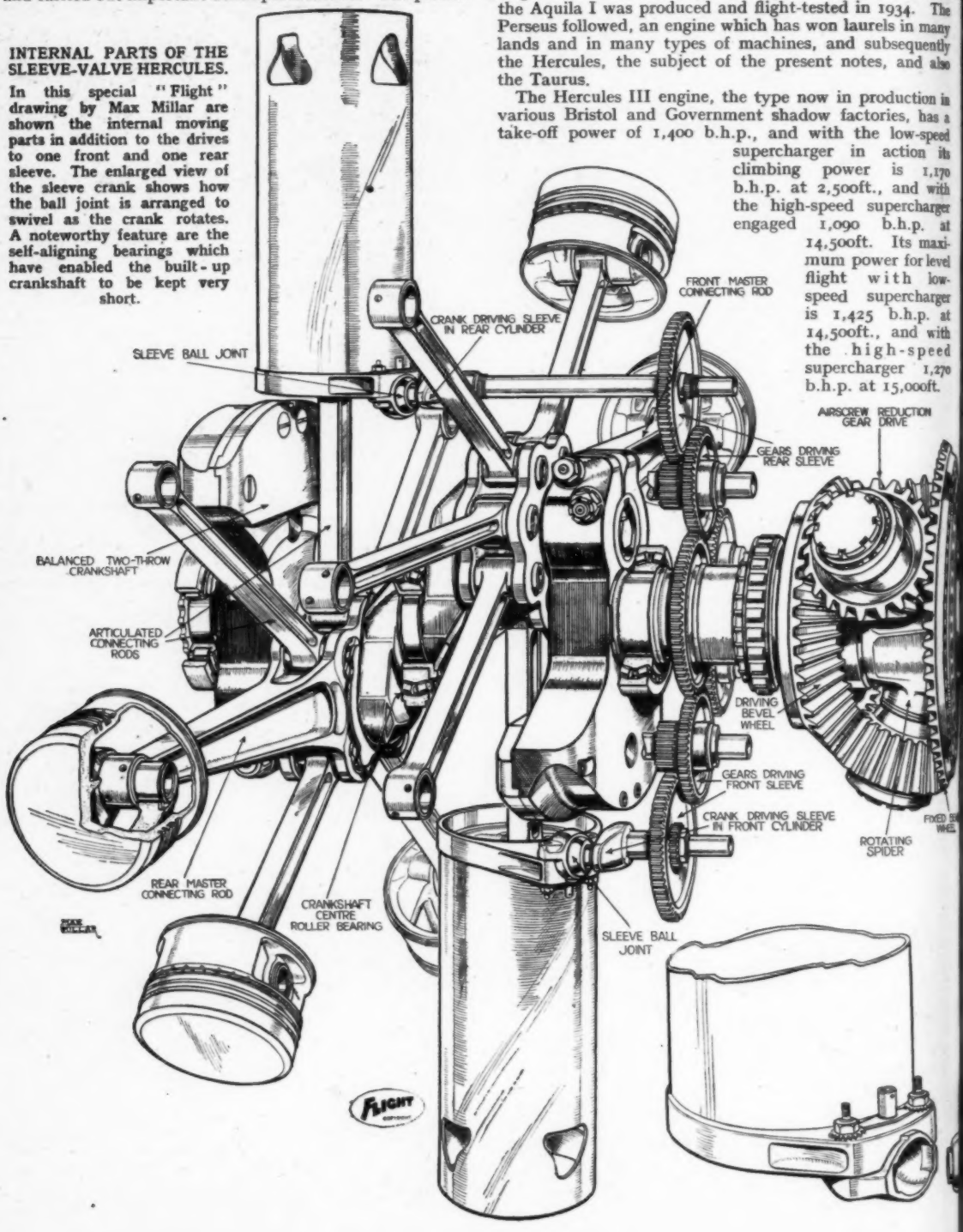
the British Government in 1914. That particular engine was a six-cylinder in-line of 785 cu. in. capacity and gave 130 b.h.p. After the war renewed interest was shown in the single sleeve-valve engine because of its many attributes. Barr & Stroud produced a motor cycle engine of the type and carried out important development work. The present state of perfection has only been attained after continuous research and experiment undertaken by the Bristol Aeroplane Company, who produced their first test unit towards the end of 1927.

In 1933, as a result of valuable data obtained from the single sleeve-valve unit, the nine-cylinder engine known as the Aquila I was produced and flight-tested in 1934. The Perseus followed, an engine which has won laurels in many lands and in many types of machines, and subsequently the Hercules, the subject of the present notes, and also the Taurus.

The Hercules III engine, the type now in production in various Bristol and Government shadow factories, has a take-off power of 1,400 b.h.p., and with the low-speed supercharger in action its climbing power is 1,170 b.h.p. at 2,500ft., and with the high-speed supercharger engaged 1,090 b.h.p. at 14,500ft. Its maximum power for level flight with low-speed supercharger is 1,425 b.h.p. at 14,500ft., and with the high-speed supercharger 1,270 b.h.p. at 15,000ft.

INTERNAL PARTS OF THE SLEEVE-VALVE HERCULES.

In this special "Flight" drawing by Max Millar are shown the internal moving parts in addition to the drives to one front and one rear sleeve. The enlarged view of the sleeve crank shows how the ball joint is arranged to swivel as the crank rotates. A noteworthy feature are the self-aligning bearings which have enabled the built-up crankshaft to be kept very short.



DATA OF HERCULES III

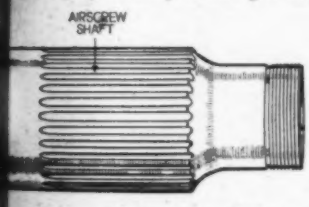
14 cylinders, double row, air-cooled radial	
Bore of cyl.	5¾in. (146mm)
Stroke of cyl.	6½in. (165mm)
Cubic capacity	2,360 cubic in. (38.7 litres)
Overall diam.	52in.
Airscrew Reduction Gear Ratio	0.44 : 1
Weight	1,850 lbs.
Take-off power	1,400 b.h.p.

The cylinder bore and stroke are 146 x 165 mm., giving a total cubic capacity of 38.7 litres. The total weight of the engine is 1,850 lb.

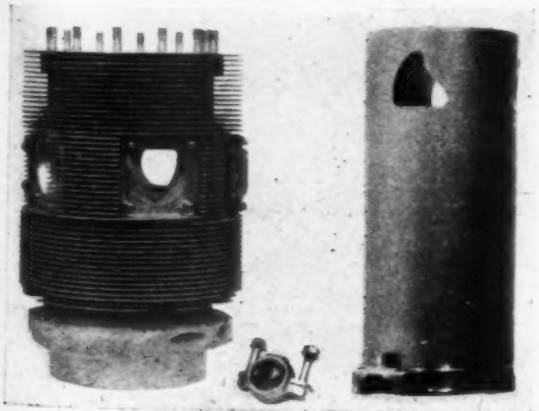
As we have stated, a feature of the Hercules engine is the single-sleeve valve, simple and attractive from the designer's and production engineer's points of view as compared to cuff valves, rotary valves or the more usual poppet valves. In a table of comparative data of sleeve- and poppet-valve engines of identical size, the cylinder assembly weight is found to be lower in the case of the single-sleeve engine than in the case of the four poppet-valve push-rod engine with which it was compared. Also a much greater cooling fin area was provided, and the b.m.e.p. superior to the poppet-valve engine both with 87 and 100 octane fuel. The b.h.p./sq. in. piston area was 5.05 for the sleeve-valve as compared with 4.18 for the push-rod engine.

It is in the operation and elliptical action of the single-sleeve valve that this type of engine shows such superior performance and lasting qualities over previous types of sleeve-valve engines.

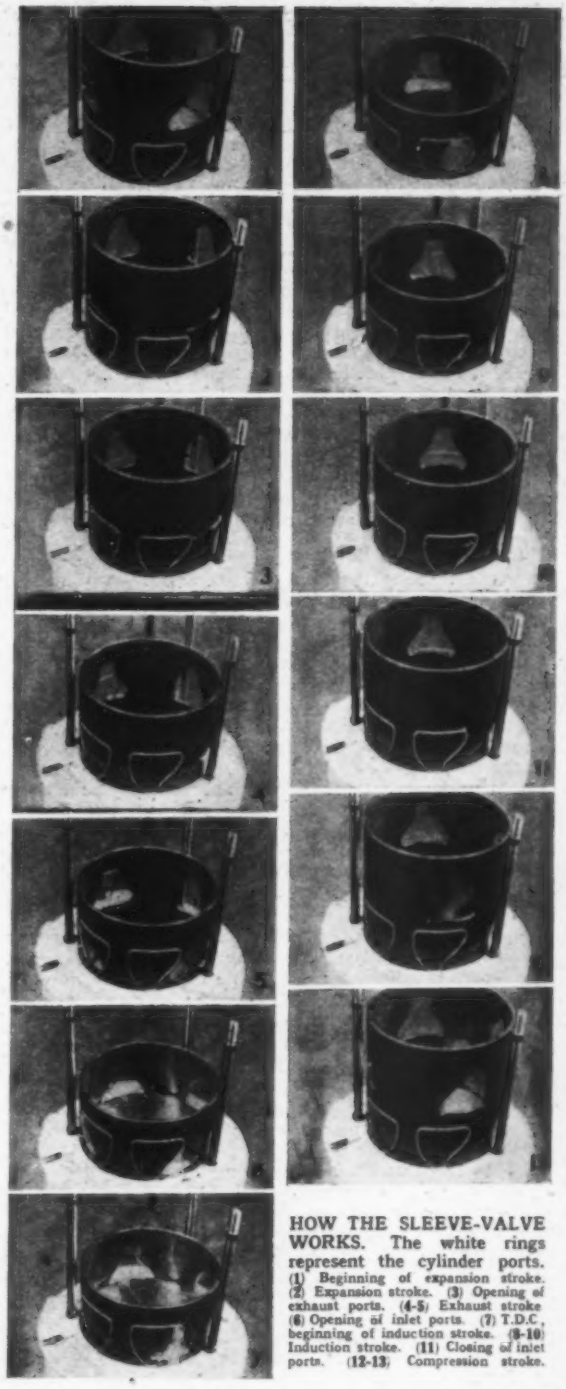
Reference to the illustrations show that the sleeve is provided with a spherically seated bearing which can swivel so that it remains in line with the pin of a small crank. The drive is performed by the rotation and sliding motion of the pin in the bearing and by the swivelling motion of the latter in its housing. The small cranks are driven by a train of gears inside the front cover. Thus it will be seen by a study of the pictures that the sleeve performs a corresponding rotary action which in itself is beneficial from the point of view of distributing the lubrication film, and, incidentally, assists cooling. There are ports in the sleeve which admit and expel the charge as they register with corresponding ports in the cylinder proper.



The cylinders, each of which is secured to the crankcase by twelve studs, are staggered; the exhaust ports are in front, the inlet ports at the rear. As an aluminium alloy blank, a cylinder barrel weighs 76 lb., but, after being provided with the close-pitched cooling fins and machined all over, the weight is reduced to 25 lb.



Ported cylinder ball joint and sleeve of the Hercules.



HOW THE SLEEVE-VALVE WORKS. The white rings represent the cylinder ports. (1) Beginning of expansion stroke. (2) Expansion stroke. (3) Opening of exhaust ports. (4-5) Exhaust stroke (6) Opening of inlet ports. (7) T.D.C., beginning of induction stroke. (8-10) Induction stroke. (11) Closing of inlet ports. (12-13) Compression stroke.

A special type of die-cast Y-alloy cylinder head is used, and the casting is so good and clean that the fins on the head need no machining.

The pistons are machined from aluminium alloy drop stampings, have flat crowns and short skirts. Three gas rings and two scraper rings are fitted. An alloy steel crankshaft built up in three pieces is employed, supported in three main self-aligning roller bearings. The connecting-rods are of the usual Bristol type, with master and articulated rods having H-section shanks.

The two-speed supercharger is mounted at the rear of

THE BRISTOL HERCULES

the crankcase and driven through hydraulically operated clutches from a torsion shaft splined into the rear of the crankshaft. It is of the gear-driven centrifugal type, introduced by the Bristol Company. The impeller, which is double shrouded, is of aluminium alloy, and the ports milled out of the solid on machines operated by women. When operating in the high-speed gear the impeller runs at over 20,000 r.p.m.

Inside the nose casing of the engine is the bevel epicyclic type reduction gear which drives the constant-speed airscrew at rather less than half crankshaft speed.

Independent ignition is provided by two magnetos, and there are two plugs per cylinder. The high-tension leads are carried in a special screened harness to eliminate radio interference.

Lubrication of the engine is by main pressure feed at 80 lb./sq. in., but a device is provided whereby this pressure may be increased to 200 lb./sq. in. for starting, thus enabling the engine to be opened up to full take-off speed immediately without detriment. The pressure automatically returns to normal when the engine becomes warmed up.

Engine Auxiliaries

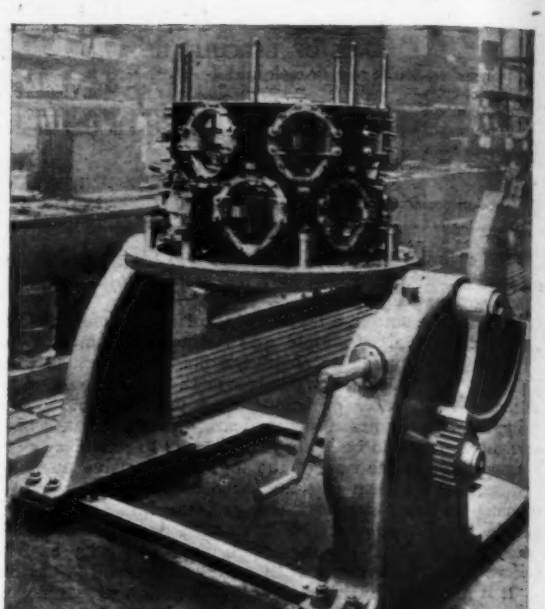
Other essential accessories, such as oil and petrol pumps, are mounted on a cover attached to the rear of the supercharger unit, and there is also provision for driving a remote accessory gear box. This gear box is an item pioneered by the Bristol Company, and it considerably simplifies installation. The unit is capable of accommodating six accessories, such as electric generators, hydraulic pumps for undercarriage, flap and gun turret operation, vacuum pumps for instrument operation and air compressors.

A downdraught carburettor incorporating automatic boost and mixture controls is employed.

A point about the sleeve-valve engine which is not generally appreciated is that no timing of valves is necessary, nor, indeed, possible. Once the pins are inserted in the spherically seated bearing of the sleeves, the valve timing is automatic.

In a paper that Mr. A. H. R. Fedden, chief engineer (Engine Department) of the Bristol Aeroplane Company, read in 1939 before the Royal Aeronautical Society on sleeve-valve development, the most important inherent advantages of sleeve-valve designs were set out as follows:

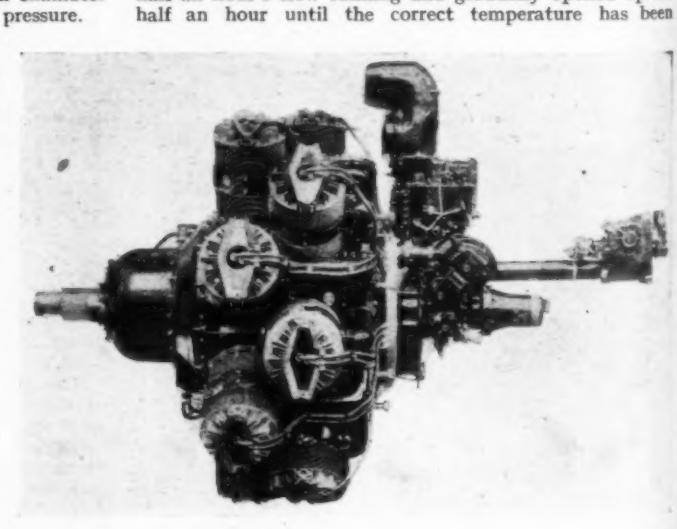
(*a*) Total absence of maintenance except for plug and magneto servicing.
(*b*) Elimination of hot spots in the combustion chamber.
(*c*) Use of higher compression ratios or boost pressure.
(*d*) Improved volumetric efficiency due to greater effective port areas.
(*e*) Centrally situated plugs, giving, if necessary, good performance on single ignition.
(*f*) Very flat mixture loops, permitting smooth running under conditions of extreme economy.
(*g*) Smooth running due to good combustion chamber shape, and to the accurate and simple valve timing.
(*h*) More silent operation.
(*i*) Good accessibility and clean exterior appearance.
(*j*) Complete enclosure of all working parts absence of external oil leads, and impossibility of oil leakage.
(*k*) Cooler exhaust.
(*l*) Freedom from lead corrosion.
(*m*) Greater freedom from cold corrosion.
(*n*) Regular cylinder shape, permitting the simplest form of baffling.



A Hercules crankcase mounted on a tilting assembly stand in the erecting shop.

(*o*) Marked decrease in number of parts, and consequent reduced production and maintenance costs.
(*p*) Relative simplicity of all major parts, permitting accurate repetition machining.
(*q*) Probability of easier operation when exhaust turbo-blowers are used.
(*r*) Greater reliability due to most of the causes mentioned above.
(*s*) Any desired control of cylinder turbulence with its possible application to stratified charges and abnormally weak mixtures with petrol injection.

In touring one or other of the several large factories dispersed north and south of the country busily producing Hercules engines, it is impressive to note the mass of parts being progressed through the shops finally as major sub-assemblies to the erecting bays. In the various test houses the procedure is to motor the engine round for three hours after which it is stripped. Subsequently the engine is given half an hour's slow running and gradually opened up for half an hour until the correct temperature has been



In this side view may be seen the downdraught carburettor and gear box drive for the accessories at the back of the engine.

THE BRISTOL HERCULES

reached, when each engine is expected to give off its rated power for one hour. After that, acceleration tests, check for take-off power, as well as slow-running tests, are made, which occupy a further two and a half to three hours.

From a production viewpoint, a new factory recently inspected in the N.W. is laid out on most modern lines, and incorporates up-to-date plant of all types which will bear comparison with engine factories of the world. Extensive use of female labour has been made possible largely by (a) breaking down operations to their most simple form, and (b) the introduction of simple, foolproof and ingenious jigs and fixtures. The success of female labour is all the more remarkable when the extremely close manufacturing tolerances are considered, these being sometimes in the nature of plus or minus two-ten thousandths of an inch.

Of the major components the cylinders provide a particularly good example of the skill of Bristol's planning engineers. There are three banks of closely spaced fins, two concentric with the bore and the other, in the centre, eccentric. In all they total 60. The sides of each fin are slightly tapered, and the depth of those near the head is varied to provide better cooling conditions. The two concentric banks are produced simultaneously in a Maxicut lathe equipped with 76 single-point tools, 38 in the front and 38 at the rear. To obtain the necessary taper on the fin sides the cylinder is set over at a slight angle, the rear tools cutting one side of the fins and the front tools the other. The eccentric fins are cut with a bank of narrow circular milling cutters mounted on a head, which is moved in and out by means of a large cam on the work head, thereby duplicating the eccentric cylinder profile.

Ingenious special-purpose machines have been developed by James Archdale and Co., Ltd., for milling the difficult port contours, one type incorporating a milling head which operates inside the cylinder. To obtain a parallel bore under hot running conditions each end of the cylinder is slightly tapered.

The production of the sleeve is an engineering triumph. Due to the fact that this component is only 0.139in. thick, although approximately 14in. long by 6in. diam., distortion from the true circular shape occurs after practically every machining operation. So delicate is the sleeve that a sharp knock is sufficient to cause distortion. To overcome this difficulty, which is enhanced by the hard nature of the Nitralloy steel from which it is made, a complicated system of numerous external and internal grinding operations are introduced throughout the manufacturing sequence, with the result that after final honing the sleeve is both accurate and true to limits of two-ten thousandths of an inch

Manufacture of the master connecting rods has been split up into more than a hundred operations to enable the employment of semi-skilled labour. As with all other steel parts on this engine the component is tested for cracks or inclusions with Magnaflux equipment, the rod being magnetised and then dipped into a fluid containing finely divided metallic particles which lie along the edge of the crack or defect As a rule the cracks, if present, are only a few thousands of an inch deep and cannot be detected with the naked eye. However, in service they are liable to lead to fatigue cracks, finally resulting in fracture.

A large proportion of the machine tools used throughout the factory are of American manufacture, but they are all of the latest types, including one of the few super-finishing machines installed in this country. With this equipment journals and cylindrical parts may be finished with a smoothness of 1-2 micro-inches (i.e., millionths of an inch) There is also an Abbot Profilometer capable of measuring to these fine limits.

A more detailed examination of the production technique employed in Hercules factories will appear in the January issue of our sister journal "Aircraft Production."

HERE AND THERE

Captain Balfour's Return

CAPTAIN H. H. BALFOUR, M.C., M.P., Under Secretary of State for Air, returned last week from his official mission to the United States in connection with supplies to Russia.

Mr. W. A. Harriman and the Rt. Hon. C. R. Attlee travelled to this country in the same aircraft.

Profit from Sale of Clippers

PAN AMERICAN AIRWAYS are reported to have made a gross profit of $806,200 from the sale of the three Boeing flying-boats to Great Britain at $1,035,400 each, "certified and delivered to Miami."

This item is quoted in the October 1st issue of *American Aviation*, and emanates from the report of a Civilian Aeronautics Board examiner on the company's Pacific air mail finances.

S.B.A.C.s New President

THE Council of the Society of British Aircraft Constructors elected a new President in Mr. A. F. Sidgreaves, O.B.E., at a special meeting held immediately after their 25th annual general meeting. He succeeds Sir Frank Spriggs, who has been President since July, 1939. Sir Charles Bruce-Gardner, M.I.Mech.E., is the permanent executive Chairman of the Society.

Mr. Sidgreaves, who is 59, is managing director of Rolls-Royce, Ltd., chairman of Bentley Motors, Ltd., and a director of Rotol Airscrews, Ltd. He began his career in the Napier works and served for some time with the Royal Naval Air Service and the Royal Flying Corps in the war 1914-18. Later he joined the production side of the Air Ministry, returning to Napier's after the war. He moved to Rolls-Royce, Ltd., in 1920, and has been managing director of the company since 1929.

Mr. J. D. North, managing director of Boulton Paul Aircraft, Ltd., was elected Vice-President (Aircraft) in succession to Mr. F. Handley Page; and Mr. C. C. Walker, technical director of the de Havilland Aircraft Co., Ltd., was elected Vice-President (Engines) in succession to Mr. H. J. Thomas, of the Bristol Aeroplane Co., Ltd., Mr. R. H. Dobson, a director of A. V. Roe and Co., Ltd., was again elected Honorary Treasurer of the Society.

The Duke of Kent touring the factory with Mr. Handley Page when he went to see Halifax production.

Correspondence

The Editor does not hold himself responsible for the views expressed by correspondents. The names and addresses of the writers, not necessarily for publication, must in all cases accompany letters.

"AB INITIO" AD. A.T.A. ?

Primary Training for Ferry Pilots

AN attempt is being made to persuade the Minister of Aircraft Production to sanction *ab initio* flying training for ferry pilots, to enable persons without "A" licences and 50 hours' solo to qualify for the Air Transport Auxiliary.

Through the medium of *Flight* I should like to appeal to anyone interested to get in touch with me at 9, Osborn Road, Farnham, Surrey.

M. CHARLES.

JET PROPULSION OF AIRCRAFT

Two Kinds to Consider

BEFORE Mr. Fernie's letter, I had not noticed much more difference between "Jet" and "Rocket" than between "Airscrew" and "Propeller." Unlike the proverbial rose, however, there are only two kinds of jet propulsion: (1) In the atmosphere, at comparatively slow speeds when it is necessary to augment the mass of the discharge with air to get practical results; (2) outside atmospheric resistance, when efficiency is obtained by speed comparable with the discharge, which are ideal conditions.

Experience suggests the possibility of mildly discharged gases in the atmosphere clinging to the moving body, but if gas particles are violently thrown back from a moving body in empty space, it would be an astounding thing if they persisted in clinging to the body. The greater part of Mr. Fernie's letter makes it quite plain that he has not read your interesting articles on jet propulsion which started the correspondence on that subject.

For the benefit of others who may have read his letter only, I venture to deal with it as follows. It cannot be assumed that the behaviour of a rocket *in vacuo* is the same as that for a rocket in an atmosphere, and no one does assume it; but because it is dependent upon the rate of discharge of the gases the propulsive effort is less in atmospheric pressure.

I fully endorse Mr. Fernie's faith in the future of Astronautics (though I should prefer a nice Planet), but to his demand for the world's best designer I must say "Of what?" To his request for a planned programme of research I must say "By whom?" Lastly, if a journey to the moon will not be feasible for ten years, what "production" should we put in hand now?

The obvious thing to have is an Interplanetary Society in which both science and scientists of every required kind could be *developed*. Pre-war work done by the British Interplanetary Society is enough to show that an experimental journey to the moon would be feasible almost as soon after getting adequate finance as some new giant aircraft could be completed.

R. C. ABEL.

Rockets or Thermal Jets

MR. M. C. FERNIE, in a letter published in your Correspondence page, on November 13th, criticising my statement regarding the problems of jet propulsion, seems himself to be in a dilemma regarding the true definitions of jet and rocket propulsion. To substantiate this statement I will quote a passage from an article by Mr. G. G. Smith, which appeared in *Flight* recently. He says: "There is, however, a fundamental difference (between jet propulsion and rocket propulsion). In rocket propulsion, the oxygen necessary for combustion is embodied in the explosive substance employed. For thermal jet propulsion, the oxygen required for the combustion of the fuel is taken from the surrounding atmosphere."

Of course, if it were possible to equip a machine of the *jet propulsion* type with oxygen tanks, it could function in space—the principles of reaction are the same. It could then hardly be termed as a true jet-propelled machine, however, for the apparatus required for the induction of the air and also the air compressors could be dispensed with. And now, what have we?—a combustion chamber, an exhaust tube and a petrol tank. It remains only to add, for example, a liquid oxygen tank and we have the four main features of a *rocket-propelled machine*.

K. W. GATLAND,
Secretary, Astronautical Development Society.

More Powerful Fuel Needed

YOUR correspondent, Martin C. Fernie, asserts that K. W. Gatland seems to be in a bit of a muddle, but he appears to be in a far greater muddle himself.

K. W. Gatland does not assume that jet propulsion in the absence of an atmosphere is not possible, but that jet propulsion in the form that *Flight* has reviewed in a series of excellent articles recently—namely, where air is used together with some other injected fuel as the means of combustion—is not possible where there is an absence of atmosphere. Further, that jet propulsion or "rocket reaction propulsion" of the form which is independent of oxygen for combustion is definitely possible where there is an absence of atmosphere.

Martin C. Fernie asks, "Wherein lies the difference?" He then, perhaps not knowing, states the difference, namely, "air," and then proceeds to cancel out this difference.

What is perhaps not realised is that there are two distinct forms of jet reaction propulsion.

First, the form which, as before stated, employs air as the main fuel, and which (as K. W. Gatland states) is not likely to be a great success due to the great resistance of the atmosphere in which it is forced to travel.

Secondly, there is the type of jet reaction propulsion which is entirely independent of the elements of the atmosphere, and which, consequently, can travel in the vacuum of outer space where the power needed would be minute, and the resistance would be nil.

Martin C. Fernie refers to the effects of gravitational fields. It is true that huge amounts of energy will be needed to propel a jet-propelled craft to points where gravitation is very small, and that such great energy cannot be developed with even the most powerful fuels which are known to exist to-day. For this reason (among others) I agree with M. C. Fernie that the world's greatest scientists, designers and experimentalists should be brought together and given all the facilities needed for experimenting on a huge scale.

One of their greatest objects would be to discover and develop a fuel, perhaps even going so far as the disintegration of the atom, which would be able to give this huge energy needed.

WILLIAM B. RICHARDSON,
M.A.D.S., S.Tech.I. (Gt. Brit.).

THE IDEAL TRAINER

Later Instructional Stages Considered

AS one who for his sins was condemned for years to teach people to fly, perhaps I may be permitted a few words on the above subject.

The ideal trainer is one on which efficient pilots can be trained quickly, with safety and economy. When efficiency and speed are considered the whole period of training, and not merely that initial period during which the trainer is to be used, must be studied.

A pupil who receives his *ab initio* training on a monoplane having flying characteristics, and instrument and control positions, approximating those of the types he will fly at later stages, will obviously need less additional training when he passes to the next stage, and thus valuable time will be saved in reaching at least the same standard of efficiency.

A high rate of climb will reduce the amount of time at present expended in gaining a safe height for practising aerobatics and spinning. Really good forward view will save time by obviating the necessity for the present method of taxying along a serpentine path in order to see what is in front of the nose. Fuel capacity should be sufficient to enable the trainer to be flown continuously for approximately four hours, and so do away with frequent refuelling delays.

With regard to safety, so many liberties can be taken with the present lightly loaded trainers that, despite all the vigilance of instructors, dangerous faults sometimes creep in, particularly in the case of the over-confident pupil, and may at a later stage lead to a crash involving the loss of a whole crew. This is not a plea for a trainer full of vices, but for one which will expose faulty flying immediately and in no uncertain manner.

When considering economy the whole period must again be

studied. The characteristics suggested will probably necessitate using more power, and this in turn will mean a heavier aircraft. The increased first costs and running costs, however, will be small when compared with the saving at later stages when flying "per hour" becomes really expensive.

Both cockpits should be enclosed. We all know that a good instructor never gets heated, but he cannot do his best work, and a pupil will not absorb his instruction so readily, if both are sitting in super-cooled misery. Anyone who has regularly given six or seven hours dual a day throughout the winter will speak with some feeling on this point.

Very high speed is a disadvantage in a trainer; not only is it expensive, but pupils will lose themselves even more easily than they do at present. Stalling speed should be 50-55 m.p.h. This will not only give landing characteristics nearer to those of present Service (and civil) types, but also enable flying to go on in winds which cause present trainers to be grounded. The side-by-side trainer has the advantage of enabling the instructor to see what his pupil is doing, but against that is the psychological effect of that empty seat during the early solo stages, and, in addition, some pupils show a regrettable tendency to land one wing down, and to do all manœuvres in one direction, when trained on this type.

The disparity between present *ab initio* trainers and those in use for advanced training is so great that many pupils have to be taught to fly again almost from the beginning, and much time is wasted through this overlapping.

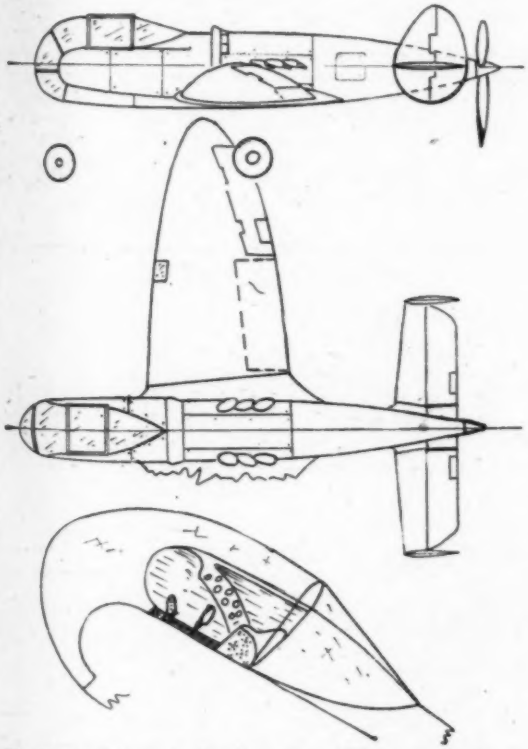
Perhaps other instructors can be persuaded to air their views on the subject.

"MASTER INSTRUCTOR."

FIGHTER DESIGN

Six Main Requirements

FOR some time now my head has been buzzing with a fighter design, and once again I turn to your journal to unburden myself. I sincerely hope, by the way, that Mr. "Prophet Without Honour" will not mind this "Learned young stripling of basic principles" cluttering up your pages yet again!



The ideal fighter embodies six main points, as far as I can see: Speed, manœuvrability, armour, armament, visibility and easy maintenance. I enclose drawings of a layout that seems to embody all these to a maximum degree. I wonder that no prototypes have appeared with the propellers pushing behind the plane, as this seems to allow for numerous advantages.

The position of the pilot in the nose gives him a view that would be hard to surpass, especially if some instrument board arrangement like the one in the accompanying diagram were adopted.

It might be said that the pilot has little armour in front when attacking a bomber. This is true. But the more orthodox interceptors could handle the bombers, while the type under discussion could take on the escorting fighters. In fighter *v* fighter, the pilot would have excellent protection from the most important point—the rear.

Finally, the manœuvrability would also be improved by the position of the armament, which could be heavy and centrally placed. The centrally placed engine, of course, adds the final touch as far as manœuvrability is concerned.

P. TAYLOR.

CATAPULTED FIGHTERS

Avoiding Aircraft Loss

BEING a Scotsman, the loss of the fighters catapulted in defence of convoys far out at sea rather worries me, so may I suggest, through the medium of this journal, that if four or five cables were suspended between two of the ships steaming on parallel courses, and these cables were at a depth of a few feet, when the aircraft "touched down" between the ships the cables could be raised by winches and the aircraft supported until salvaged?

This suggestion may have the possible disadvantages of weight and impracticability in rough weather. The former should not be great as the ships would need to be no more than 60 or 70 feet apart; and, if the weather was too bad for this plan to be used, it is hardly likely that aircraft would be able to operate.

May I also suggest that the effect of blast, shrapnel and low-flying cannon or m.g attacks on dispersed aircraft on the ground could be easily eliminated by throwing up two walls of brick, so familiar in the old pattern surface air-raid shelters, at the various dispersal points?

E. J. MORAN CAMPBELL.

CONTRA-ROTATING AIRSCREWS

Interference Velocities

IN reply to Mr. Williams' letter in your November 6th issue, I would like to explain that the diagram concerned was purposely drawn without reference to number of blades for the sake of simplicity. In any case, vectors AB and BC were referred to as "net velocities," so that those well versed in the intricacies of airscrew theory would regard them as including the axial and rotational interference velocities appropriate to the given number of blades.

Further, it is desired to make clear that if both blade angle and operating J are being simultaneously varied, it is not true that a given pitch difference between front and rear screws can necessarily achieve perfect torque balance for only one condition of flight.

For the De Havilland Aircraft Company, Ltd.,
A. V. CLEAVER,
Technical Assistant (Airscrews), Engineering Dept.

The First Co-axial Design

CONGRATULATIONS on the way you are keeping up interest in *Flight*. I was particularly glad to see that article of Shackleton's in your issue of October 30th. He seems to have settled the contra-prop-torque controversy for good.

But I notice that nobody, so far as I have seen, has yet mentioned the fact that the first co-axial contra-prop was that which Howard Wright, Warwick Wright's brother, showed at the Aircraft Show at Olympia in, I think, early 1910.

It was, in fact, merely two props mounted on the same axis and driven by an ordinary differential gear. Howard's theory was that if the props themselves were correctly designed (I nearly said "prop"erly) the resistance of the blades of each would balance out the other and so they would go round in opposite directions. Obviously, if one had more resistance than the other, it would go slower and the other would go faster.

Perhaps you might dig that matter up and get some of your torque-experts, or talk-experts, to do a fresh talk about torque.

"OLD HAND."

[In the Howard Wright airscrew, shown at the first Olympia aero show in March, 1909, the two units were of unequal diameters, the front being larger and absorbing two-thirds of the power. The two units ran at the same speed, viz., one-third of the engine speed.—ED.]

BARREL ENGINES

More Power from Less Engine : How to Develop 5,000 h.p. from 3,000 lb. Weight and 7 sq. ft. Frontal Area

By E. S. HALL

THE basic object of all aircraft-engine development is to get more power from less engine. The usual procedure is to improve current types, an example being the increase in output of the nine-cylinder radial from 400 h.p. to 1,200 h.p. in 14 years, without change in its 16 sq. ft. of frontal area or its displacement, and with an increase in weight of only 50 per cent. This method is good business until it gets into the region of diminishing returns. Then it becomes more profitable to use the other method: to start with a clean sheet on the development of a better type of engine—one capable of performance beyond any that can be hoped for from current types.

The tendency is to stay too long with the improvement method because of engineering habit and the investment. Although this condition improves the opportunity to come in with a better engine, the new engine must be decidedly better. No new design of the same old types will do. The clean-sheet method must be applied with a careful search of all mechanisms and combustion systems for the one best combination. The purpose of this paper is to aid in that search.

THE author, who is manager of the Round Engine Patents, examines six barrel engine mechanisms in this paper, which was presented at the National Aeronautic Meeting of the American Society of Automotive Engineers last year. By combining the good features of all, he arrives at some startling results. The paper is reproduced here by courtesy of the S.A.E. Journal, with a selection from the numerous illustrations of the original.

A survey of this sort, to be useful, has to be critical. The best engine form, mechanism, combustion system, or combination thereof, is best not so much because of its virtues as because of the worse faults of the alternatives. To apply the process of elimination, it is necessary to see faults as well as virtues.

Engine Form or Shape

The best engine form for high-speed flying is that having the lowest power plant drag. The engines compared in Fig. 1 are in the 2,000 h.p. class with the same displacement, cycle, valves and rating. They differ essentially only in cylinder arrangement. On the basis of engine form alone, you would not choose the radial. Clever cowling has cut down the disturbance of its fat face, but engine form drag still tends to be proportional to frontal area. The reason for the current tendency to revert to in-line types is their lower head resistance. Follow through with this reasoning: The engine which "flies through the air with the greatest of ease" is the barrel engine, with cylinders parallel to the shaft. You wouldn't shoot a bullet sideways. Why push cylinders that way?

The barrel engine packs a surprising piston displacement behind a modest face, the advantage increasing with engine size. In a barrel engine

$$\text{piston displacement} \propto (\text{engine diameter})^3.$$

Depending on the choice of mechanism, number of cylinders, and stroke/bore ratio, the piston displacement may be 3,000 to 5,000 cu. in. with an engine diameter of 30in.; 5,000 to 8,000 cu. in. with an engine diameter of 36in.; 15,000 to 30,000 cu. in. with the diameter of a 2,000 cu. in. single-row radial.

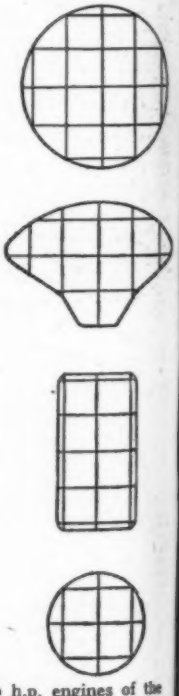
Compactness of the barrel engine is one of the reasons why it can be developed to fill William B. Stout's order: 100 h.p.—100 lb.—$100. A step in that direction is the 50 h.p. two-stroke barrel engine designed by Lee Oldfield, and recently flight-tested. A 100 h.p. four-stroke engine of 230 cu. in. piston displacement need be only 12in. in diameter.

For the largest power outputs, the greater relative compactness of the barrel engine puts it into a class by itself. Other engines can cut their form resistance as low only by being submerged in the wing, but the additional weight of that installation more than offsets its advantage. No matter how you look at it, the barrel engine has the least drag for its power by a wide margin. But what good is a streamlined figure if it will not work? Is it possible to build a mechanism for converting piston thrust parallel to the shaft into shaft rotation, able to stand up as well as does the crank mechanism? But how good is this standard, the crank mechanism?

The Crank Mechanism

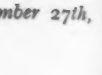
If the crank mechanism in an aircraft engine could have cross-heads, piston action could be so much more precise. Trunk pistons, too short to stay coaxial with the cylinders, slap and cock and upset ring action, preventing attainment of the best performance.

Connecting-rod angularity makes the piston go over top centre much faster than over bottom centre. This is bad in three ways: (1) It is the worst source of unbalance; (2) inertia forces over top centre run 25 per cent. higher than they would with harmonic motion, so the rings lose their seats by their own inertia, and blowby jumps at correspondingly low speed; (3) and if the engine is pushed to its utmost performance where time for combustion is



Two-row Radial Engine 18 cyl.
Frontal Area - - - 16 sq. ft.
Engine Drag h.p.
at 20,000ft. - - 373 h.p.
at sea level - - 700 h.p.

Double Allison Type - 24 cyl.
Frontal Area - - - 12 sq. ft.
Engine Drag h.p.
at 20,000ft. - - 280 h.p.
at sea level - - 525 h.p.



H-Type Engine - - - 24 cyl.
Frontal Area - - - 10 sq. ft.
Engine Drag h.p.
at 20,000ft. - - 233 h.p.
at sea level - - 436 h.p.

Barrel Engine - - - 18 cyl.
Frontal Area - - - 6 sq. ft.
Engine Drag h.p.
at 20,000ft. - - 140 h.p.
at sea level - - 263 h.p.

Fig. 1. Frontal areas of various 2,000 h.p. engines of the same displacement and their respective drag horse-power in nacelles at 400 m.p.h.

BARREL ENGINES

the limiting factor, shaft and piston speeds with the crank mechanism must be 12 per cent. slower than they would be for the same combustion time if the piston motion were harmonic. The performance that would be possible with harmonic motion must be discounted 12 per cent. for the dubious privilege of using the crank mechanism.

This discount is not ordinarily felt because other defects of the crank mechanism prevent the speed from approaching the range where it comes in. One of these is useless connecting-rod loading, inertia loading without offsetting pressure in three out of four piston strokes, and heavy centrifugal loading, the latter especially bad in the radial where the centrifugal load on the master-rod bearing is three to five times the useful load, and getting worse as speeds increase, increasing with the square of the speed.

In short, we put up with the defective crank mechanism because we do not know any better. There is no excuse for using it if we could find a barrel-engine mechanism as much superior as the form of the barrel engine is better for aircraft purposes than that of any other engine type.

Barrel-engine Mechanisms

Almost the only barrel-engine literature is that found in about a thousand patents, all of which show only a half-dozen different mechanisms. Of these the bevel-gear type, with individual radiating crankshafts geared to a common shaft, retains the faults of the crank mechanism and adds the weakness of gears which must take the reversal of loading on the same teeth every cycle. The most promising arrangement is that shown in Fig. 2, in which the crankshaft pinions mesh with gears on oppositely rotating propeller-shafts. The single-ended conic crank mechanisms do not make the most of barrel-engine compactness and are otherwise unsuitable for high-performance engines. The same may be said for the angular rotary mechanisms in which the cylinder blocks rotate about an axis making an angle with the shaft axis.

The three remaining types are: (1) the swashplate and slipper mechanism, with the swashplate fixed on the shaft and the slippers pivoted in the piston member; (2) the cylindrical cam mechanism, with roller cam followers on bearings in the piston members; and (3) the wabbler mechanism, in which the wabbler is mounted on bearings on and inclined to the shaft, the rim of the wabbler connected with the pistons in one of several ways.

(1) *Swashplate and Slipper Mechanisms.*—An early barrel-engine patent is that granted to Jabez Coney, of Boston, dated 1856. The slippers are hemispherical, seated in sockets screwed axially through the pistons. The flat faces of the slippers co-act with the swashplate. Jabez Coney realised that he had much capacity in a small package. "The pump is compact in form . . . and will throw the same quantity of water at each revolution, whatever be the speed."

The "straight-through" piston member is entirely contained within the cylindrical limits and is capable of being passed straight through the cylinder. This is essential to compactness and simplicity in a barrel mechanism, for if the piston member extends beyond these cylindrical limits, room for the reciprocating of the excrescence must be provided, increasing the length and weight of the machine.

About sixty years later A. G. M. Michell, as an outgrowth of his work on pivoted slipper thrust bearings, invented the swashplate-slipper mechanism again (Fig. 3). Others also tried it, but Michell applied the principles of fluid-film lubrication and made it work efficiently. He also showed that its piston motion is harmonic and that the piston inertia couple can be balanced exactly by the centrifugal couple of the swashplate to produce mathematically perfect dynamic balance.

Michell-Crankless engines have been in commercial operation for years. This mechanism has excellent mechanical efficiency. Slipper action is known to be efficient, and the slipper speed limit of 200 ft./sec. which

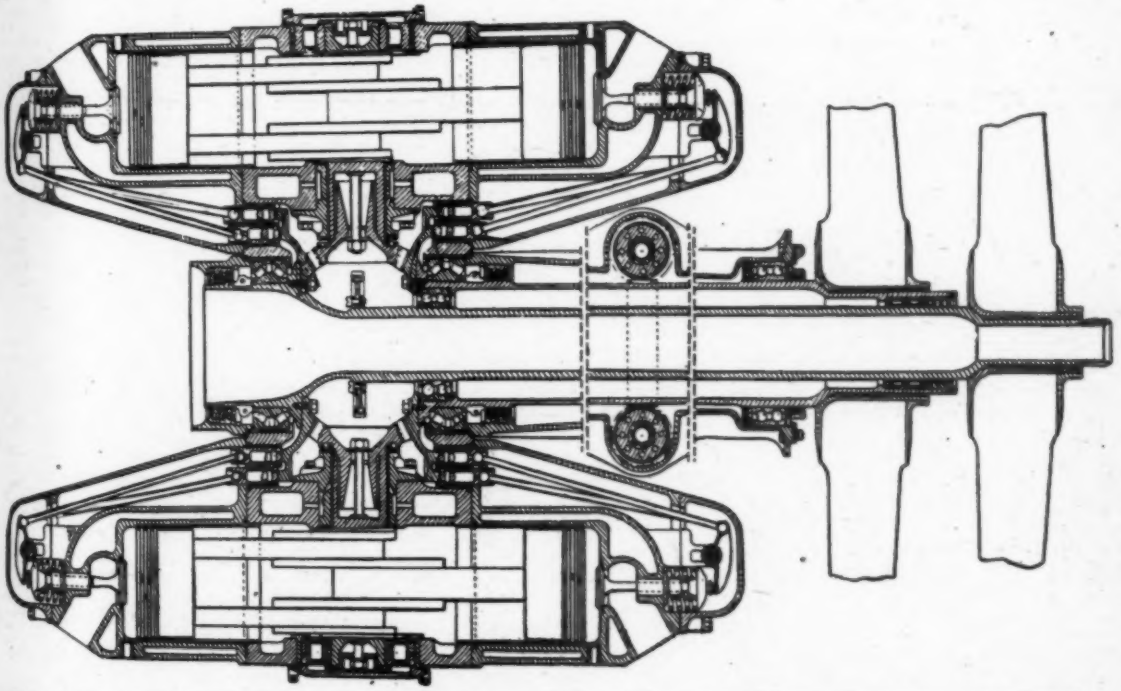


Fig. 2. Bevel-gear engine with oppositely-rotating airscrews. Reported to be under development by Regnier, and invented by E. Gadoux and L. Crousse, 1936-40.

BARREL ENGINES

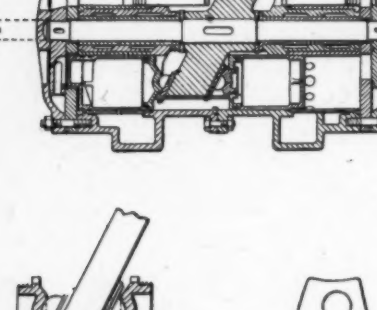


Fig. 3. Swashplate-slipper air compressor. Inventor A. G. M. Michell, February 5th, 1924. Mechanism for the interconversion of reciprocating and rotary motion.

prevailed formerly has been removed by more care in keeping the "slant" well oiled.

Slipper reaction includes heavy components of piston side-thrust radial to the shaft. These components, useless in producing torque, increase piston friction and bend the piston member where it is weakest because of being notched to clear the swashplate. Consequently, the straight-through piston unit, essential to simplicity and minimum length, cannot have enough strength and rigidity in this mechanism for high-duty service.

In an engine of this type built in 1929, the piston member was mounted on slipper guide bearings to accommodate its bending. Cramping of the main slippers due to flexure of the piston member may have contributed to their failure whenever attempts were made to bring this engine up to power.

The construction now favoured seems to be that using two guide rods for the cross-head to slide on. For a rigid piston member to operate on such guides, they would have to be exactly parallel to the cylinder axis and the right distance apart, impossible conditions with changing stress and temperature. One rod is therefore given the load, and the other eccentrically mounted to serve only to prevent rotation of the cross-head about the first. As further insurance against cramping, a jointed connecting rod may be used between the piston and cross-head.

The difficulties arising from the useless radial components of slipper reaction in this mechanism involve more length, weight and complication than desirable in trying for the highest specific performance.

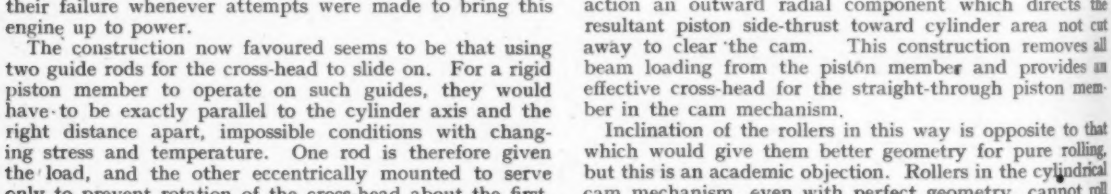
(2) *Cylindrical Cam Mechanisms.*—Most of the many cam mechanisms proposed have been unnecessarily complicated. Their peculiar troubles can be avoided by using simpler designs.

The cylindrical cam mechanism of ultimate simplicity is that of Karl L. Herrman (Fig. 4). Counterweights and balancing problems are avoided by using the two-throw cam, making the pistons balance themselves and providing a half-speed shaft, desirable in an aircraft engine. Roller and pin troubles were eliminated by forming half-journal bearings in the piston members, permitting each roller and pin to be integral. Straight-through piston members are practicable in the cam mechanism because of the absence of components of piston side-thrust inwardly radial to the shaft. Even so, the one-sided inertia pull on the bridge combined with the off-centre beam loading from roller reaction tangential to the cylinder circle, caused trouble with piston deflection and breakage.

Removing Beam Loading

The undesirable loading can be avoided by inclining the rollers with their axes meeting at a point farther removed from the shaft. This design permits a smaller cam and a thicker bridge section, and gives the roller reaction an outward radial component which directs the resultant piston side-thrust toward cylinder area not cut away to clear the cam. This construction removes all beam loading from the piston member and provides an effective cross-head for the straight-through piston member in the cam mechanism.

Inclination of the rollers in this way is opposite to that which would give them better geometry for pure rolling, but this is an academic objection. Rollers in the cylindrical cam mechanism, even with perfect geometry, cannot roll without sliding. Their own flywheel reaction will not per-



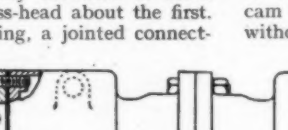


Fig. 4. The simplest cylindrical cam mechanism and radial view of piston member. Karl L. Herrmann, 1936.

mit them to accelerate and decelerate enough for pure rolling on the changing gradient of the cam. Pure rolling may not be desirable; gear teeth fail at the pitch line rather than at points where the contact is both rolling and sliding.

Contact of the roller and cam is a point or a line, without area. The materials deform under load until enough contact area is produced to support the load. The cam loading is the more critical because the peak roller loads come repeatedly on the same point on it. It is well to study loading conditions of each design because improvement sometimes can be made by running at faster piston speeds or by making the piston members heavier, increasing the inertia loading relative to the gas pressure loading to shift the points of maximum loading from the convex parts of the cam to the concave positions where contact area with the roller can be developed with less deformation. Loading conditions are also much better with two-stroke cycle than with four-stroke, as will be discussed later relative to the wabbler mechanism.

Effect of Size

Herrmann seems to be demonstrating that the cam can stand up in a small engine if the material, heat-treatment, and precision of the cam are excellent. Double the bore, and the piston thrust at a given piston speed increases four times. The contact area between the roller and cam must be four times greater for the same specific loading, and the deformation to produce such an area is apparently twice as great as with the smaller bore. But the deformation which the cam material can stand without failure is independent of size. Will a point be reached, as size increases, where the cam will be unable to stand the loading long enough to be useful?

Final answers will be found only by experience with enough cam engines. The life and dependability of the cam mechanism may even now be satisfactory for service in which the life of the engine is otherwise limited. Certainly a cam engine with a pair of rotary plate valves fixed on its half-speed shaft, the shaft serving also as the intake manifold, is a type that could be produced in quantities in a hurry at half the cost per horse-power of any aircraft engine now in production.

(3) *Wabbler Mechanisms.*—An obvious way to connect pistons to a wabbler plate is by connecting rods. The connecting rods must be universally jointed because of the three-dimensional movement of the wabbler. Correct wabbler motion is symmetrical. Similar points in the wabbler plane describe identical loci having the form of a spherical lemniscate* (Fig. 5). In end view, this lemniscate is a small circle of diameter $= R$ versine ϕ, in which R is the radius of the point in the wabbler plane, and ϕ is the angle of inclination of the wabbler from normal to the shaft. The point revolves about this small circle at a rate twice shaft speed and in the same sense.

Torque Reaction

How the wabbler turns the shaft without rotating itself can be understood from a consideration of forces on a wabbler arm at mid-stroke position (Fig. 5). The piston thrust P, acting upon the arm as a lever with a force P sec ϕ, exerts a push upon one end of the Z-crank pin and a pull on the other end, turning the shaft. The plane of action of the wabbler arm lever being inclined to the piston-thrust, the reaction produces side pressure, P tan ϕ, on the wabbler arm joint. This is the torque reaction; the manner in which it is transmitted to the fixed parts of the engine determines whether the wabbler mechanism is a good one or not.

Most wabbler mechanisms impose the engine torque reaction upon the wabbler. This is obvious when connecting rods are used. If the wabbler were not held against rotation, piston thrust would merely turn the wabbler on its bearing, tangling up the rods and producing no shaft rotation. A wabbler restraint capable of carrying the torque reaction while maintaining true wabbler motion has been hard to find.

* A figure 8 on the surface of a sphere.

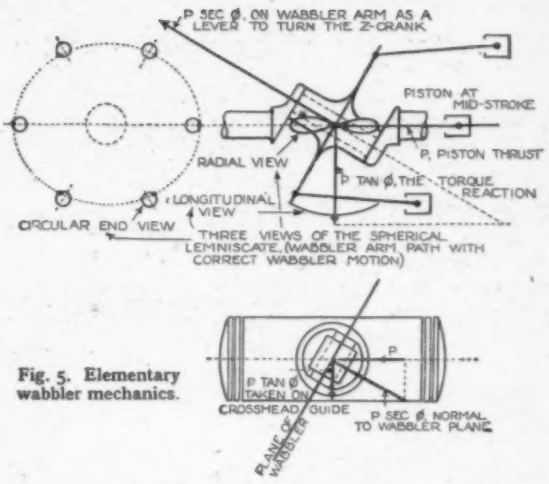

P SEC Ø, ON WABBLER ARM AS A LEVER TO TURN THE Z-CRANK
PISTON AT MID-STROKE
P, PISTON THRUST
RADIAL VIEW
P TAN Ø, THE TORQUE REACTION
LONGITUDINAL VIEW
CIRCULAR END VIEW
THREE VIEWS OF THE SPHERICAL LEMNISCATE (WABBLER ARM PATH WITH CORRECT WABBLER MOTION)
P
P TAN Ø TAKEN ON CROSSHEAD GUIDE
P SEC Ø, NORMAL TO WABBLER PLANE
PLANE OF WABBLER

Fig. 5. Elementary wabbler mechanics.

Any restraint which distorts the wabbler motion, such as a Hooke joint, a link swinging from the casing, or any arc slider which compels a point on the wabbler to remain in one place, introduces a mean vibration at twice shaft speed, undesirable in a high-performance engine. In the Bristol bus engine the tail of the Hooke joint was wagged by linkage with an eccentric on a layshaft running twice engine speed, to approximate true wabbler motion. Nevatt shows bevel gears inside the wabbler to avoid the bastard gears usually necessary when outside bevels are used. These and similar wabbler restraints are not wholly satisfactory, and ball-jointed connecting rods are not the most respectable machine elements.

Alternative Method

A simpler joint for connecting pistons to the wabbler has a large-diameter piston pin with a transverse hole in it receiving a radially extending wabbler arm pin. This mechanism is simple and compact. However, it has inwardly radial components of piston side-thrust like those in the swashplate mechanism, and, if true wabbler motion is to be maintained, the piston pins must all have axial freedom in the pistons, some other means being provided for restraining the wabbler from rotation against the torque reaction. Usually one of the piston pins is axially fixed in the piston, in which case the entire engine torque reaction is taken by this one piston, the stroke motions of the several pistons are not equal, and the double-time vibration is present.

One way to avoid some of these troubles is to make the wabbler arms independent so that each arm can remain in the plane of the cylinder and shaft axes. This construction is similar to the independent connecting rods in the Le Rhône rotary engine, but, in this case, the cantilever loading on the connections of the arms with the hub are not desirable, and it is not easy to design an adequate hub structure within the available space. Similar limitations apply when using a master arm and knuckle pins corresponding to the construction in radial engines.

The circular end view of the lemniscate (Fig. 5) can be applied as a wabbler restraint. Almen used this principle in some of his earlier engines, and extended it also to prevent rotation of the piston members by offsetting the two control elements in each piston, one to one side of the piston axis and the other to the other side. Nevatt, in a recent patent, revived the old idea of using the circular end view of the lemniscate as a wabbler restraint. These constructions require precision in indexing both cylinders and wabbler arms, and with the load being passed from one arm to the next, chances for quiet operation are not too good.

(To be continued.)

Service Aviation

Cheers for the King when His Majesty arrived to inspect an Avro Manchester squadron.

Royal Air Force and Fleet Air Arm News and Announcements

Awards

THE KING has been graciously pleased to approve the following awards in recognition of gallantry displayed in flying operations against the enemy :—

DISTINGUISHED SERVICE ORDER.

Act. Wing Cdr. H. M. STYLES, No 407 Squadron.—This officer has displayed rare powers of leadership and organising ability. As commander of the squadron he has played a large part in raising it to its present high standard of operational efficiency. The squadron has been responsible for destroying or severely damaging many thousands of tons of enemy shipping.

Act. Wing Cdr. Styles has himself contributed materially to the splendid achievements, carrying out his attacks from low altitudes and in the face of intense anti-aircraft opposition. This officer has set a magnificent example of courageous leadership and determination.

BAR TO THE DISTINGUISHED FLYING CROSS.

Sqn. Ldr. O. J. M. BARRON, D.F.C., No. 220 Squadron.—Since July, 1941, this officer has participated in several determined attacks on enemy shipping. He has also attacked two oil factories on the Norwegian coast; direct hits were obtained on the factory buildings in each instance. On another occasion Sqn. Ldr. Barron carried out a sortie against an enemy aerodrome in Denmark. Although his aircraft was severely damaged by fire from the ground defences, he released heavy bombs on an aircraft dispersal area.

In October, 1941, Sqn. Ldr. Barron participated in a very successful exploit against shipping at Aalesund. Skilfully manœuvring his aircraft, he reconnoitred the position and then attacked the largest ship, which subsequently sank. He then flew over the harbour and enabled his gunners to machine-gun anti-aircraft positions, two of which were silenced. This officer has displayed great leadership, and his determination in the face of the enemy is most praiseworthy.

Flt. Lt. J. R. D. BRAHAM, D.F.C., No. 29 Squadron.—Since January, 1941, this officer has carried out many operational sorties at night, during which he has destroyed six hostile aircraft, bringing his total victories to at least seven destroyed, one probably destroyed and a further two damaged. His most recent success was one night in October, 1941, when he intercepted a raiding aircraft, and, following a burst from his guns at short range, the raider went down in flames, finally crashing into the sea. This officer has always shown the utmost zeal and keenness, and has flown with great skill in adverse weather conditions on many occasions.

Flt. Lt. P. H. HUGO, D.F.C., No. 615 Squadron.—Since early in September, 1941, this officer has participated in numerous attacks on enemy shipping, during which some 35 vessels have been either sunk, set on fire or damaged; also several E boats were damaged in two further attacks. Other losses sustained by the enemy were a petrol storage tank which was set on fire, and one of their aircraft destroyed.

In the execution of operational tasks necessitating the greatest skill and determination, Flt. Lt. Hugo has displayed high qualities of leadership and courage. Although he has been continuously engaged on operational flying since the war began his enthusiasm remains unabated.

DISTINGUISHED FLYING CROSS.

Act. Sqn. Ldr. E. H. THOMAS, No. 611 Squadron.—This officer has been actively engaged in operational flying since August, 1940, when he fought in the Battle of Britain. He has participated in 60 sorties over enemy territory since the beginning of 1941, and has destroyed at least three enemy aircraft and shared in the destruction of another; he has also damaged an enemy patrol ship. Since assuming command of the squadron, Sqn. Ldr. Thomas has consistently displayed great skill and leadership and has contributed materially to its high morale.

F/O. W. H. H. HOLLAND, R.A.F.V.R., No. 220 Squadron.—One night in October, 1941, whilst engaged on a reconnaissance flight over Norwegian waters, this officer observed an enemy escorted convoy. He attacked the largest vessel and obtained two direct hits. In spite of heavy opposing fire, he pressed home his attack at such low altitude that his aircraft actually struck one of the ship's masts. Later in October, F/O. Holland participated in a highly successful exploit at Aalesund, obtaining a direct hit on a vessel, and afterwards flew over the town and machine-gunned German barracks.

F/O. K. W. J. TARRANT, R.A.F.V.R., No. 220 Squadron.—In October, 1941, this officer was the captain of an aircraft which participated in a raid on shipping in the harbour at Aalesund. In the ensuing attack, F/O. Tarrant obtained direct hits on a 2,000-ton merchant vessel, setting it on fire. He then attacked a fish-oil factory with incendiary bombs and machine gun fire. A deep red glow was observed from inside the factory.

Throughout, his aircraft was subjected to heavy fire from the ground and ship defences, but this did not deter him from pressing home his attacks with great determination. F/O Tarrant has completed 300 hours' operational flying, including many attacks on shipping, during which he has obtained several successes.

Roll of Honour

Air Ministry Casualty Communique No. 91.

THE Air Ministry regret to announce the following casualties on various dates. The next-of-kin have been informed.

Royal Air Force

KILLED IN ACTION (WHILE FLYING IN OPERATIONS AGAINST THE ENEMY).—P/O. C. W. Abrey; Sgt. J. Aitken; Sgt. F. Dunn; Sgt. I. J. Green; Sgt. R. Hayden; Sgt. V. C. Hayward; Sgt. J. G. Jones; Sgt. L. D. Kissack; Sgt. G. O. Linhart; Sgt. H. Martin; Sgt. B. Morgan; Sgt. D. Richardson; Sgt. H. A. Verrells; Sgt. J. S. F. Watt; Sgt. G. B. Watters; P/O. S. A. Wells; Sgt. J. L. Whitfield.

PREVIOUSLY REPORTED MISSING BELIEVED KILLED IN ACTION, NOW PRESUMED KILLED IN ACTION.—F/O. S. V. Alderton; Wing Cdr. R. G. C. Arnold; Sgt. C. T. F. Baldwin; Sgt. D. J. R. Craig; P/O. R. H. Crush; Sgt. A. C. Fletcher; Sgt. J. R. Fraser; Flt. Sgt. S. R. Gear, D.F.M.; Sgt. K. P. Glassborow; Act. Wing Cdr. W. H. Graham; Sgt. G. T. Hall; Sgt. I. P. Hunter; F/O. G. J. Lynes, D.F.C.; P/O. P. Myers; Sgt. E. G. Norman; Sgt. G. A. Selby; Sgt. R. A. Spyer; Sgt. W. K. Thompson; F/O F. S. W. Webb.

PREVIOUSLY REPORTED MISSING, NOW PRESUMED KILLED IN ACTION.—Sgt. E. G. Abraham; F/O. N. Le C. Agazarian; F/O. P. T. Anderson; Sgt. D. W. Arkwright; Sgt. L. A. Arrighi; Wing Cdr. J. E. M. Bainbridge; Sgt. J. K. Barker; Sgt. D. C. Beddow; Sgt. J. Bowes; Sgt. J. D. Bramhall; Sgt. H. G. Browne; Sgt. L. C. Butcher; Sgt. G. H. Carter; Sgt. K. J. Cooper; P/O. E. F. Cragg; Sgt. R. L. Dingle; Sgt. I. H. Fenton; Sgt. R. A. Freestone; P/O. R. J. Fyfe; Sgt. J. C. Greig; Sgt. E. S. C. Halsall; F/O. R. L. Hicks; Sgt. E. Hughes; Sgt. T. S. H. Hunter; Sgt. A. Jackson; Sgt. O. M. Jenkins; Sgt. N. F. Johnson; Sqn. Ldr. F. J. Kelly; Sgt. B. Kipling; Sgt. A. E. Laing; Sgt. T. O. Lewis; Sgt. J. McI. McDonald; Sgt. W. McIntosh; Sgt. T. P. O'Byrne; Sgt. J. A. Patterson; Sgt. J. R. C. Pratt; P/O. J. K. C. Ralston; Sgt. H. Sheard; Sgt. W. F. Sidaway; Sgt. D. A. Smithies; Sgt. S. W. Snoddon; Sgt. A. R. Taylor; Sgt. W. E. Tilley; F/O. R. F. Turner.

PREVIOUSLY REPORTED MISSING BELIEVED KILLED IN ACTION, NOW REPORTED KILLED IN ACTION.—A/C.1 J. W. Cutchie.

WOUNDED OR INJURED IN ACTION.—Sgt. J. E. Blackburn; Sgt. G. S. W. Challen; Sgt. P. J. Hay; P/O. S. S. Hordern; Sgt. A. O. Humble-Smith; Sgt. J. W. Hurley.

MISSING BELIEVED KILLED IN ACTION.—Sgt. J. B. Bell; Sgt. D. Blake; P/O. H. S. Brown; Sgt. T. W. Bull; Sgt. H. A. French; Sgt. T. D. Griffiths; Sgt. D. C. Hayward; Sgt. A. R. Hulls; Sgt. E. S. Jones; P/O. F. A. Letchford; Sgt. G. A. Painting; Sgt. R. B. Russell; Sgt. G. H. Spickett; Flt. Sgt. F. Tweedale.

MISSING.—Sgt. C. W. Baker; Sgt. A. F. Binns; Flt. Lt. A. M. Brown; Sgt. J. B. Crees; Sgt. J. A. McC. Crothers; Act. Wing Cdr. J. K. M. Dryedale, D.S.O.; Sgt. H. N. Edge; P/O. T. G. Edwards; Sgt. M. E. Farnan; Sgt. B. L. Fitsell; P/O. W. R. Gardiner; P/O. J. C. Greenfield; Sgt. D. P. Hawkes; Sgt. H. Hobbs; Sgt. G. M. Holstead; Sgt. J. Horabin; F/O. R. E. M. Hughes-Chamberlain; F/O. I. D. Jeremy, D.F.C.; Sqn. Ldr. R. A. L. Knight, D.F.C.; Sgt. P. J. Lewis; P/O. D. W. Lintern; Act. Flt. Lt. J. W. Lund; P/O. A. G. Milne; Act. Sqn. Ldr. P. W. O. Mould, D.F.C.; P/O. I. Murchie; P/O S. G. Nicoll; Sgt. J. Nightingale; Sgt. K. G. Port; Sgt. W. N. Pratt; P/O. R. Purvis; Sgt. E. A. Redfern; Sgt. J. H. Sherriff; Act. Sqn. Ldr. F. J. Soper, D.F.C., D.F.M.; F/O. J. F. Swift, D.F.C.; Flt. Sgt. J. D. Truscott; Act. Flt. Lt. W. C. Ward; P/O N. P. Warden; Sgt. R. G. Wernham; Flt. Sgt. W. C. Wheatley.

MISSING BELIEVED KILLED ON ACTIVE SERVICE (WHILE ENGAGED ON NON-OPERATIONAL FLYING DUTIES OR ON THE GROUND THROUGH ENEMY ACTION).—L.A/C. J. F. C. Cliffe; Sgt. R. L. Kitch.

KILLED ON ACTIVE SERVICE.—Sgt. J. Amott; Sqn. Ldr. K. L. Ashfold; Sgt. G. F. Baker-Benfield; Sgt. D. T. Bicknell; Sgt. F. J. Bull; Sgt. W. T. Douglas; Sqn. Ldr. K. H. A. Ellis, D.F.C.; Sgt. K. D. Greenwood; Flt. Sgt. R. E. Hall; Sgt. J. K. Howe; A/C.2 E. B. Jones; P/O. R. A. McAnany; L.A/C. R. P. Marshall; P/O. I. Prentice; Sgt. P. E. Ritter; A/C.2 R. Secker; A/C.2 W. J. Talbot; Sgt. T. J. W. Thomas; P/O. E. J. Tuckey; Sgt. J. H. Vaughan; L.A/C. C. D. Walker; Sgt. J. G. Wallace; Sgt. E. M. White; L.A/C. A. V. Zanzottera.

PREVIOUSLY REPORTED MISSING, NOW PRESUMED KILLED ON ACTIVE SERVICE.—Sgt. F. H. Baldwin; A/C.1 E. Bradbury; P/O. G. B. Chapman; Sgt. D. C. Craig; Sgt. G. Date; Sgt. J. Orr; Sgt. W. J. Savage; Sgt D. Strachan.

PREVIOUSLY REPORTED MISSING BELIEVED KILLED ON ACTIVE SERVICE, NOW REPORTED KILLED ON ACTIVE SERVICE.—P/O H. J. Talbot.

WOUNDED OR INJURED ON ACTIVE SERVICE.—L.A/C. J. R. A. Stead.

DIED OF WOUNDS OR INJURIES RECEIVED ON ACTIVE SERVICE.—L.A/C. F. Birchwood; L.A/C. A. M. Chadwick; L.A/C. M. H. Chiverton; L.A/C. N. C. H. Clout.

DIED ON ACTIVE SERVICE.—Act. Sqn. Ldr. W. K. Birch, O.B.E.; Sgt. G. P. F. Bryant; Cpl. A. P. Davis; A/C.1 E. J. Dowle; Cpl. K. E. Evans; Wing Cdr. G. Farnhill; Cpl. J. McKie; A/C.1 L. Martlew; L.A/C. A. L. Packham; A/C.1 W. J. Sherborne; Sgt. J. Toogood; A/C.2 W. F. Wattis; Flt. Sgt. W. A. Wiggin; L.A/C. J. J. Wood; A/C.1 R. Wornsop.

PREVIOUSLY REPORTED MISSING, NOW REPORTED PRISONER OF WAR.—Cpl. L. W. Bayes; Sgt. R. S. Beattie; A/C.2 A. E. Clark; A/C.2 J. E. Craig; L.A/C. F. E. Crundwell; L.A/C. J. Cunliffe; Cpl. E. A. Dear; A/C.1 J. Duff; L.A/C. E. Dullaghan; L.A/C. J. Edwards; Sgt. G. A. Fairbank; A/C.1 A. T. Foster; Cpl. A. C. Harrison; A/C.1 J. Hynd; Cpl. R. T. Jones; Cpl. R. J. Lawrence; A/C.2 A. Lonsdale; A/C.2 W. H. Lumsden; A/C.1 J. McL. Macfadyen; L.A/C. I. McD. MacQuarrie; Cpl. H. Mitchell; A/C.2 N. H. C. Northover; A/C.2 J. Riley; Cpl. A. C. Russell; L.A/C. K. J. Stone; L.A/C. R. Tweddle; A/C.2 C. A. Underwood; A/C.1 F. Walkingshaw; A/C.1 B. J. Williams.

Royal Australian Air Force

WOUNDED OR INJURED IN ACTION.—Flt. Lt. J. H. Saunders.

MISSING, BELIEVED KILLED IN ACTION.—Sgt. J. H. Goodey; Sgt. J. M. McCullough.

MISSING.—Sgt. C. K. Berriman; Sgt. J. F. Cash; Sgt. H. G. Waler.

KILLED ON ACTIVE SERVICE.—Act. Cpl. H. G. Boulter; Act. Cpl. O. M. Connors; Sgt. W. D. R. Ellis; P/O. F. N. Grant.

DIED ON ACTIVE SERVICE.—A/C.1 D. J. Buckle; P/O. J. C. Osborne.

Royal Canadian Air Force

KILLED IN ACTION.—Sgt. J. W. Humphrey; P/O. J. B. Ruston.

PREVIOUSLY REPORTED MISSING, NOW PRESUMED KILLED IN ACTION.—P/O. I. MacLean.

DIED OF WOUNDS OR INJURIES RECEIVED IN ACTION.—Sgt. R. Craig.

MISSING, BELIEVED KILLED IN ACTION.—P/O W. K. Colfe; Sgt. A. G. Geddes; Sgt. J. A. D. Rheaume.

MISSING.—Sgt. J. W. Archibald; Sgt. W. B. Clark; Sgt. G. E. Findlay; Sgt. A. Harkness; Sgt. K. A. Irwin; Sgt. J. S. Lappin; P/O. C. C. Lowther; P/O. R. G. Sutherland; P/O. C. S. White; Sgt. J. F. Wolff.

KILLED ON ACTIVE SERVICE.—P/O. R. C. Colley; P/O. K. W. Hutchison; Sgt. W. F. Smith.

WOUNDED OR INJURED ON ACTIVE SERVICE.—Sgt. G. D. Noton.

Royal New Zealand Air Force

KILLED IN ACTION.—Sgt. J. D. Broadley.

WOUNDED OR INJURED IN ACTION.—Sgt. S. F. Hall; P/O. L. B. Renolds.

KILLED ON ACTIVE SERVICE.—Sgt. T. S. Hewland.

South African Air Force

PREVIOUSLY REPORTED MISSING, NOW REPORTED PRISONER OF WAR.—Capt K. W. Driver

HISTORIC PHOTOGRAPH : Taken just before the now famous advance into Abyssinia which started on February 10th, 1941, it shows officers of the combined headquarters of the R.A.F. and S.A.A.F. in the East African Command. Outnumbered by the Italian Air Force, the small South African Air Force operated in an area of 275,000 square miles under gruelling conditions. In fourteen months, an average of 200 sorties a month were made over enemy territory. Operations were brilliantly directed by the A.O.C. Air Commodore W. Sowrey, D.F.C., A.F.C., of the R.A.F.

Left to right—1st row (sitting)—Major J. A. de Vos, Captain O. Galgut, Brigadier H. C. Daniel, M.C., D.F.C. (Senior Air Staff Officer, S.A.A.F.), The A.O.C. Air Commodore W. Sowrey, D.F.C., A.F.C., Lt. Col. H. J. Bronkhorst, S/Ldr. M. F. Poulter, S/Ldr. R. H. Bennett. 2nd row—F/O. B. M. Grover, Major S. L. Curlewis, 2nd Lt. H. G. Stevenson, F/Lt. J. C. Green, D.F.C., F/O. R. Graham-Bell, Lt. Miss N. D. Graham (W.A.A.F.), 2/Lt. J. R. E. Neame, Capt. F. O. Bales, F/Lt. A. E. C. Forrest, Major G. N. Robertson, Capt. T. S. Harrison, D.F.C. 3rd row—S/Ldr. H. Waite, F/Lt. W. K. Harris, S/Ldr. H. Stones, S/Ldr. E. H. McDonald, Major A. V. Paterson, 2/Lt. H. Nicholas, Lt. S. R. Caine. 4th row—Lt. J. F. Barry, S/Ldr. C. E. Hawkins, W/Cdr. D. A. Wilson, S/Ldr. S. F. Tolman, 2/Lt. O. E. I. Measroch. 5th row—S/Ldr. E. B. Green, M.C., P/O. J. L. Byrne, M.C., Lt. J. R. Scott, F/O. F. O. S. Dobell, 2/Lt. I. A. Maisels.

SERVICE AVIATION

Indian Air Force

MISSING, BELIEVED KILLED IN ACTION.—P/O. R. N. Dastur.
MISSING.—P/O. C. P. Khosla.

Casualty Communique No. 92

THE Air Ministry regret to announce the following casualties on various dates. The next-of-kin have been informed.

Royal Air Force

KILLED IN ACTION (WHILE FLYING IN OPERATIONS AGAINST THE ENEMY).—Sgt. H. L. Carter; Sgt. A. E. Cosgrove; Cpl. S. J. Edwards; P/O. C. B. K. Fry; Sgt. T. D. Graham; P/O. J. R. Harrison; Sgt. T. Hunter; Sgt. H. C. Lee; Sqn. Ldr. D. I. McLeod; Sgt. J. A. Marshall; Flt. Sgt. A. A. Nordon; P/O. P. F. Opperman; Sgt. A. Pilkington; Sgt. D. A. Ryder; Act. Flt. Lt. S. G. Stock, D.F.C.; Sgt. R. H. Todman; Sgt. F. H. N. Tothill; Flt. Sgt. J. R. Walker; Flt. Sgt. H. Watson; Sgt. C. J. L. Whiteford.

PREVIOUSLY REPORTED MISSING, BELIEVED KILLED IN ACTION, NOW PRESUMED KILLED IN ACTION.—P/O. H. Badland; Sgt. C. R. Burch; Sgt. W. G. H. Dauncey; Sgt. A. H. H. Hazell; Sgt. R. T. Henderson; Sgt. J. A. Keates; P/O. H. Martin.

PREVIOUSLY REPORTED MISSING, NOW PRESUMED KILLED IN ACTION.—Sgt. F. Archer, D.F.M.; Flt. Lt. A. L. H. Barber; Sgt. J. Bestwick; Sgt. P. J. Breene; P/O. P. R. D. Brown; P/O. F. A. Caunter-Jackson; Sgt. G. T. Cheetham; Sgt. T. H. Cooke; Sgt. T. S. Courtman; Sgt. J. G. Crawford; P/O. W. I. Dalgliesh; Sgt. W. A. L. Davidson; Sgt. J. T. Donnelly; Sgt. A. B. Ferguson; Sgt. L. R. France; Sgt. C. Gillespie; P/O. G. H. Green; Act. Sqn. Ldr. J. M. Griffith-Jones, D.F.C.; Sgt. R. Hinton; Sgt. J. N. Holdsworth; Grp. Capt. D. de H. Humphreys; Sgt. J. S. Legge; Sgt. R. L. McCarthy; Sgt. H. E. Meason; F/O. P. Moller; Flt. Lt. A. P. Pain; P/O. R. N. Philpott; Act. F/O. P. H. H. Pritchard; Cpl. W. J. Richards; Sgt. G. E. Salisbury; Sgt. K. H. A. Vaughan.

WOUNDED OR INJURED IN ACTION.—Sgt. W. H. S. Clark; P/O. J. D. Keynes; P/O. A. G. Little; Sgt. R. F. Wardle.

MISSING, BELIEVED KILLED IN ACTION.—Sgt. W. A. Brooks; Sgt. R. H. Coomber; Sgt. C. E. Earl; P/O. R. L. Lloyd; Sgt. W. E. Mortimer; Sgt. K. W. Perry; Sgt. D. G. Robb; P/O. P. J. B. Veitch.

MISSING.—A/C.1 A. C. Attwood; Sgt. R. W. Bird; Sgt. E. H. Brace; Sgt. K. R. McL. Brown; P/O. G. W. Bull; Sgt. A. E. Burrows; Sgt. H. B. Buttell; F/O. V. G. Collins; Sgt. A. R. Cooper; Sgt. C. W. Cooper; Sgt. H. Cox; Sgt. D. E. Coyle; Sgt. L. H. Ellis; Act. Flt. Lt. J. O. W. K. Ferris; W/O. A. Fletcher; Sgt. G. W. Gray; F/O. R. A. Greenhill; Sgt. V. G. Haley; Sgt. T. A. W. Hamilton; Sgt. S. R. E. Hammersley; Act. Flt. Lt. J. A. Harries; Sgt. F. Harrison; Sgt. T. H. Harrower; F/O. M. Jacoby; Sgt. S. Jones; Sgt. H. H. Judge; Sgt. J. G. C. Keeble; Sgt. W. D. Lambert; Sgt. I. McCarthy; Act. Flt. Lt. R. R. McPherson; Sgt. H. H. Mansfield; Sgt. E. G. Newnham; Sgt. L. H. Oldman; Sgt. R. N. Parker; Sgt. J. Parkin; Sgt. J. M. Patterson; Sgt. A. W. Petherick; Sgt. A. L. Roberts; Sgt. A. E. Robbins; Sgt. A. D. M. Routh; F/O. D. Shaw; Sgt. L. E. Sexton; Sgt. A. M. Smith; L.A/C. F. Teasdale; F/O. W. H. J. Thompson; Sgt. W. S. Todd; Sgt. J. Tucker; Sgt. R. R. Vosper; F/O. N. W. Walders; P/O. G. S. Walker; Sgt. H. J. Walker; Sgt. B. Ward; Sgt. J. C. Ward; P/O. W. J. White; Sgt. J. L. Whitticase; A/C.1 G. A. Widdowson; Sgt. G. E. F. Woods-Scawen.

MISSING, BELIEVED KILLED ON ACTIVE SERVICE (WHILE ENGAGED ON NON-OPERATIONAL FLYING DUTIES OR ON THE GROUND THROUGH ENEMY ACTION).—A/C.1 F. F. Addison; Sgt. E. A. Hafner; A/C.2 J. C. Marshall; A/C.2 D. J. Page; Sgt. J. Perry.

KILLED ON ACTIVE SERVICE.—Sgt. S. H. Alsop; Act. Sqn. Ldr. H. V. Barker; Cpl. C. J. Bleackley; Sgt. F. Cocking; Sgt. M. J. Counter; Sgt. A. F. Cullen; Sgt. C. Cullen; L.A/C. P. L. G. Davies; Sgt. W. Fleming; Act. Flt. Lt. A. E. Garrett; Sgt. E. J. Gill; Sgt. H. Hancock; Cpl. E. M. Harding; A/C.1 L. R. Harwood; L.A/C. (Cadet) G. W. Hogben; P/O. O. J. H. Hoskins; Sgt. D. C. Laws; Sgt. E. S. Locke; L.A/C. R. A. Lusha; P/O. H. H. McCall; L.A/C. T. N. McConnell; Sgt. A. MacKenzie; Sgt. W. Main; Act. Flt. Lt. A. Mamedoff; Act. Flt. Lt. E. J. B. Martin; Sgt. L. G. Masters; Flt. Sgt. H. H. Nettleton; L.A/C. F. K. Nield; Sgt. E. O'Grady; L.A/C. J. Pollock; L.A/C. T. A. Pryce; Cpl. P. E. Purdy; L.A/C. W. H. Richards; L.A/C. H. W. Rigley; L.A/C. R. B. Roffe; L.A/C. D. N. Roger; F/O. R. G. Setchell; L.A/C. J. C. Smith; L.A/C. W. A. Smith-Cross; A/C.2 W. K. B. Stewart; L.A/C. J. W. Stoneham; P/O. R. N. Stout; L.A/C. C. T. Stubberfield; Sgt. P. P. Stuivenga; Sgt. D. Tester; A/C.2 A. J. Truman; L.A/C. B. W. Tucker; P/O. G. S. Willsher; Sgt. P. H. T. Windett.

A 1,000-lb. bomb being fitted to a Curtiss SB2C-1 dive bomber. The bomb is carried internally and ejected before release.

PREVIOUSLY REPORTED MISSING BELIEVED KILLED ON ACTIVE SERVICE, NOW PRESUMED KILLED ON ACTIVE SERVICE.—L.A/C. J. J. Gawse; L.A/C. H. W. L. Holder; L.A/C. T. B. Hunt; L.A/C. H. C. Jones; A/C.2 E. H. Swinney.

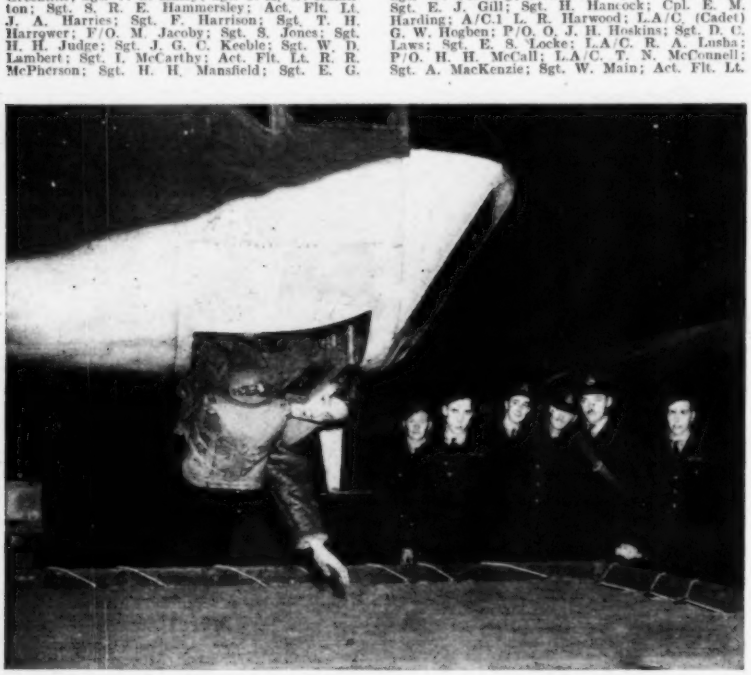
WOUNDED OR INJURED ON ACTIVE SERVICE.—A/C.2 W. Edgar; A/C.1 E. R. C. Fryatt; Sgt. J. M. C. Jenkinson; Sgt. J. F. Morris; A/C.1 A. K. Murphy; Sgt. D. A. Murphy.

DIED OF WOUNDS OR INJURIES RECEIVED ON ACTIVE SERVICE.—L.A/C. F. Dickenson; L.A/C. R. H. Hughes.

DIED ON ACTIVE SERVICE.—Cpl. E. C. Barley; A/C.2 P. R. Budd; L.A/C. J. A. D. Dicker; A/C.2 W. P. Dowell; A/C.2 R. F. Hawes; A/C.1 R. Humble; L.A/C. W. Reid; L.A/C. P. Steandy; A/C.2 E. A. W. Smart; Cpl. R. P. Watson.

PREVIOUSLY REPORTED MISSING, NOW REPORTED SAFE.—Sgt. W. G. Lockhart.

PREVIOUSLY REPORTED MISSING, NOW REPORTED PRISONER OF WAR.—A/C.1 T. Craven; A/C.1 L. Roome.



Baling-out practice from a long-nosed Blenheim at an operational training unit.

Royal Australian Air Force

KILLED IN ACTION.—Sgt. C. G. Lord; Sgt. J. G. Rich.

MISSING.—Sgt. D. J. McKenzie.

MISSING, BELIEVED KILLED ON ACTIVE SERVICE.—Sgt. H. B. Morgan; Sgt. M. W. E. Paul.

KILLED ON ACTIVE SERVICE.—P/O. M. Irvine-Brown; Sgt. P. B. T. Quint.

Royal Canadian Air Force

KILLED IN ACTION.—Sgt. W. H. Burns; Sgt. H. E. Donson; Sgt. J. L. S. Dunlop; Sgt. D. L. Kibbe; Act. Flt. Lt. F. S. Watson.

MISSING, BELIEVED KILLED IN ACTION.—P/O. H. MacL. Aitchison; Sgt. J. Altorsen; Sgt. R. C. Roberts; Sgt. C. G. Taylor; Sgt. C. C. Thomes.

MISSING.—Sgt. R. S. Hambly; Sgt. W. K. Hosing; Sgt. P. Kelly; P/O. D. S. McDonald; Sgt. G. F. Macleod; P/O. T. C. Patterson; Sgt. C. A. Whidden.

KILLED ON ACTIVE SERVICE.—Sgt. A. B. Mokanyk; Sgt. R. Wright.

Royal New Zealand Air Force

MISSING.—Sgt. K. A. Commetti; P/O. T. B. Cooper; Sgt. L. L. Thomas.

KILLED ON ACTIVE SERVICE.—P/O. C. G. Everiss.

South African Air Force

KILLED IN ACTION.—Lt. N. J. Cullum; Lt. C. A. Whaits.

WOUNDED OR INJURED IN ACTION.—Air Sgt. J. C. Inglethorpe.

DIED OF WOUNDS OR INJURIES RECEIVED IN ACTION.—Air Mech. L. Soleman.

MISSING, BELIEVED KILLED IN ACTION.—Lt. R. C. W. Miller.

omb is

. Martin;
Nettleton;
L.A/C. J.
E. Purdy;
V. Ricley;
ger; F/O.
/C. W. A.
t; L.A/C.
/C. C. W.
D. Teste;
Tucker;
ndett.
BELIEVED
PRESUMED
J. Gawne;
R. Hust;
winney.
SERVICE—
yatt; Sgt.
is; A/C.1

CEIVED ON
n; L.A/C.

C. Bailey;
O. Dicker;
ves; A/C.1
P. Sims-
F. Watson.
NOW RE-

NOW RE-
F. Craven;

Force
Sgt. J. G.

TIVE SER-
E. Paul.
M. Irvine.

Force
urne; Sgt.
Sgt. D. E.

ION.—P/O.
Sgt. R. C.
Thomson.
K. Hust-
nald; Sgt.
Sgt. C. A.
A. E.

Force
/O. T. B.
O. C. C.

orce
illum; Lt.
—Air Sgt.
CEIVED IN
CTION.—Lt.